TRANSACTIONS
American Society for Steel Treating

VOL. IX MARCH, 1926 No. 3

The object of the Society shall be to promote the arts and sciences connected with either the manufacture or treatment of metals, or both.—Constitution A. S. S. T., Art. II.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS

HOTEL STATLER, BUFFALO, JANUARY 20, 1926—9:30 A. M.

Present

R. M. BIRD, President
J. F. HARPER
ZAY JEFFRIES
W. S. BIDLE
HYMAN BORNSTEIN
R. G. GUTHRIE
W. H. EISENMAN

Absent

F. E. MCCLEARY
F. G. HUGHES

Upon motion by Mr. Harper, seconded by Mr. Guthrie and unanimously carried, the following resolution of organization was adopted:

"Resolved: In order to comply with the laws of Ohio, in which the directors of the Society elect their own officers it is hereby resolved that the following officers be elected for the American Society for Steel Treating for 1926:

R. M. Bird, president for one year
J. F. Harper, vice-president for one year
W. H. Eisenman, secretary for one year
Zay Jeffries, treasurer for two years."

The minutes of the previous meeting of the Board of Directors, held in Cleveland, on December 5, 1925, were read and approved.

Upon motion properly made, seconded and unanimously carried, the appointment of standing committees, as submitted by president Bird, was approved as follows:

FINANCE COMMITTEE

DR. ZAY JEFFRIES, Chairman
Aluminum Company of America
Cleveland

Members:
J. V. Emmons, Cleveland
J. M. Watson, Detroit
A. O. Fulton, Boston
A. G. Henry, Chicago

PUBLICATION COMMITTEE

PROF. H. M. BOYLSTON, Chairman
Case School of Applied Science
Cleveland

RAY T. BAYLESS, V. C. and Secy.
4600 Prospect Ave., Cleveland

Members:
G. C. Lilly, Lehigh Valley
C. M. Johnson, Pittsburgh
A. H. d'Arcambal, Hartford
S. C. Spalding, Syracuse
J. L. McCloud, Detroit
Jerome Strauss, Washington
E. E. Thum, New York
B. F. Shepherd, Lehigh V'y
R. S. Archer, Cleveland
A. W. F. Green, Philadelphia

MEETINGS AND PAPERS COMMITTEE

E. C. SMITH, Chairman
Central Steel Co.
Massillon, Ohio

Members:
J. H. Nead, Cincinnati
H. M. Williams, Dayton

RAY T. BAYLESS, Secretary
4600 Prospect Ave., Cleveland

CONSTITUTION AND BY-LAWS COMMITTEE

S. M. HAVENS, Chairman,
Ingalls-Shepard Division
Wyman-Gordon Co.
Harvey, Ill.

Members:
H. J. Stagg, Syracuse
H. K. Briggs, North West
W. P. Woodside, Detroit
F. H. Franklin, Providence
F. G. Hughes, Hartford

RECOMMENDED PRACTICE COMMITTEE

J. F. HARPER, General Chairman
Allis-Chalmers Mfg. Co.
Milwaukee

J. EDWARD DONNELLAN, Secy.
4600 Prospect Ave., Cleveland

Members:
J. A. Mathews, New York
G. H. Wright, Schenectady
R. B. Schenck, Detroit
W. J. Merten, Pittsburgh
F. C. Langenberg, Boston
P. C. Osterman, New York

A suggestion was made that there should be an individual on the Recommended Practice Committee representing the railroads, and it was agreed that the selection of this member should be left in the hands of the Recommended Practice Committee.

COMMITTEE ON HARDNESS TESTING OF METALS

A. E. BELLIS, Chairman
Bellis Heat Treating Co.
Branford, Conn.

Members:
H. C. Boynton
R. C. Brumfield
S. L. Goodale
H. P. Hollnagel
F. C. Langenberg
P. D. Merica
H. F. Moore
A. E. White
E. L. Wood
S. N. Petrenko
H. L. Whittemore
S. R. Williams
J. J. Curran
L. A. Lanning
H. M. German
E. E. Thum
A. L. Davis
R. T. Bayless
O. W. Boston

JOINT COMMITTEE ON HEAT TREATMENT DEFINITIONS

A. S. S. T. Representatives with A. S. T. M. and S. A. E.

J. Fletcher Harper, Bradley Stoughton, W. J. Merten

Treasurer Jeffries then submitted an unaudited treasurer's report for the year 1925.

It was moved, seconded and unanimously carried that the salary of the secretary should be $11,000.00 a year.

It was moved, seconded and unanimously carried that the salary of the editor of TRANSACTIONS should be $5200.00 a year.

It was moved, seconded and unanimously carried that the salary of the secretary of the Recommended Practice Committee should be $4000.00 per year.

The proposed budget for the year 1926 was then presented

by Treasurer Jeffries. After discussion and a few changes, it was adopted as follows:

ANTICIPATED INCOME		
Gross Dues	$41,000.00	
Transactions Advertising	43,000.00	
Transactions Sales	2,000.00	
Bindery Account	1,000.00	
Discounts Received	500.00	
Interest Received	3,350.00	
Data Sheets	2,500.00	
Book Account	1,000.00	
Miscellaneous	1,500.00	
1925 Convention	55,000.00	$150,850.00
ANTICIPATED EXPENSE		
Discounts Allowed	400.00	
Bindery Account	1,300.00	
Reprints	400.00	
Data Sheets	3,500.00	
Library	200.00	
Book Account	800.00	
Miscellaneous	1,000.00	
Transactions	37,550.00	
Secretary's Office	14,800.00	
President's Office	2,500.00	
Treasurer's Office	3,300.00	
Directors' Expenses	2,000.00	
National Committees	6,400.00	
Sectional Meetings	800.00	
Increase of Membership	1,000.00	
Local Chapters Refund	16,500.00	
Reserves	6,900.00	
1926 Convention and 1927	1,000.00	
1925 Convention and 1926	50,000.00	
E. D. Campbell Memorial Lecture	500.00	$150,850.00

Treasurer Jeffries then presented the report of the meeting of the Finance Committee, held in Cleveland on Saturday, January 9, 1926. It is as follows:

Present
DR. ZAY JEFFRIES, Chairman
A. G. HENRY
J. M. WATSON
J. V. EMMONS
Absent
A. O. FULTON

The committee visited the Equity Savings and Loan office and verified the savings deposit book with the records in the office of the Equity Savings and Loan Co..

They then visited the savings deposit vault at the East End office of the Cleveland Trust, examined and made record of the bonds contained therein, as well as the savings account at that branch of the Cleveland Trust.

Upon motion made, seconded and unanimously carried, the 1926 budget, as presented above, was voted and recommended to the Board of Directors.

Upon motion properly made, seconded and carried, bad accounts to the amount of $55.50 were authorized to be written off.

The question of investment of the Society's funds was then given thorough consideration. It was moved, seconded and unanimously carried that the committee should recommend to the Board of Directors the investment of $5000.00 in Cleveland Trust Bonds and $15,000.00 in Union Trust Bonds and that the balance be kept largely in savings accounts in three banks, the Union Trust, Cleveland Trust and Equity Savings and Loan.

It was further recommended that the checking account be continued as at present with the Cleveland Trust, due to the favorable conditions offered on both the commercial and savings accounts.

It was further voted to recommend to the Board of Directors that the Henry Marion Howe Medal Fund be increased from $3000.00 to $5000.00.

It was moved, seconded and unanimously carried that office furniture be depreciated from its present value to a book value of $500.00.

The Finance Committee reports that suit has been entered against Herman A. Holz, Inc., New York, in order to collect $250.00 due for advertising in the TRANSACTIONS.

The following items were presented for inventory:

Bindery (1964 Bound Volumes)		$1964.00
Transactions—Paper and Cover Stock		305.00
Data Sheets—Binders and Paper		58.00
		$2327.00
220 Pins @ .42 each	92.40	
19 Pencils @ 1.75 each	33.25	125.65
		$2452.65

Upon motion properly made, seconded and carried, the meeting adjourned at 5:00 p. m.

Upon motion, made, seconded and unanimously carried, the above report of the Finance Committee was accepted.

A motion was made by Mr. Bornstein, seconded by Mr. Harper and unanimously carried that the treasurer should be authorized to invest $20,000.00 in bonds as per the recommendation of the Finance Committee.

It was moved by Mr. Harper, seconded by Mr. Bidle and unanimously carried that the Henry Marion Howe Medal Fund be increased from $3000.00 to $5000.00.

It was moved by Mr. Bidle, seconded by Mr. Bornstein and unanimously carried that office furniture be depreciated from its present book value to a book value of $500.00.

Upon motion properly made, seconded and unanimously carried, an invitation was extended to the S. A. E. to hold their annual Production Meeting at Chicago during the week of the Convention of the A. S. S. T. and National Steel and Machine Tool Exposition.

Upon motion properly made, seconded and unanimously carried, the Board extended an invitation to the A. S. M. E. to hold a two-day Regional Meeting under the auspices of the Machine Tool Practice Division, during the week of the Convention of the A. S. S. T. and the National Steel and Machine Tool Exposition, at Chicago.

Upon motion properly made, seconded and unanimously carried, the Drake Hotel was selected as the official headquarters for the Convention of the A. S. S. T. and the National Steel and Machine Tool Exposition at Chicago.

Upon motion properly made, seconded and unanimously carried, a committee composed of R. G. Guthrie, J. F. Harper and W. H. Eisenman, was appointed to represent the Board in arranging for the annual Convention to be held in Chicago.

Upon motion properly made, seconded and unanimously carried, a committee, composed of W. S. Bidle, F. G. Hughes and W. H. Eisenman, was appointed to present a recommendation to the Board of Directors at its meeting in Hartford, on May 19th, relative to a 1927 convention city.

The committee appointed to investigate the advisability of affiliation of the A. S. S. T. with the American Engineering Council and the American Engineering Standards Committee reported that it did not feel justified at this time in recommending affiliation with these organizations. Upon motion properly made, seconded and unanimously carried, the report was received and approved.

Dr. Jeffries, chairman of the committee appointed to notify Hon. Elbert H. Gary of his election to Honorary Membership reported that Judge Gary had been notified of his election and had accepted Honorary Membership in the A. S. S. T.

President Bird, chairman of the committee appointed to notify Charles M. Schwab of his election to Honorary Membership, reported that Mr. Schwab had been notified of his election and had accepted Honorary Membership in the A. S. S. T. The reports were received and accepted by the Board and the certificates of

Honorary Membership will be conferred at the annual banquet at the Drake Hotel on September 23, 1926.

President Bird submitted to the Board his schedule of visits to the chapters of the A. S. S. T. for the purpose of conferring with the chapter executive committees. The report is as follows:

1. Philadelphia—January 4
   Washington—January 6
   New York—January 12
   Lehigh Valley—January 15
   Cleveland—January 19
2. Toronto—January 23
3. New Haven—Monday, February 8
   Hartford—Tuesday, February 9
   Springfield—Wednesday, Feb. 10
   Worcester—Thursday, February 11
   Providence—Friday, February 12
   Boston—Saturday, February 3
4. Pittsburgh—Monday, February 22
   Buffalo—Tuesday, February 23
   Rochester—Wednesday, Feb. 24
   Syracuse—Thursday, February 25
   Schenectady—Friday, February 26
5. Cincinnati—Monday, March 8
   Detroit—Tuesday, March 9
   South Bend—Wednesday, March 10
   Chicago—Thursday, March 11
   St. Louis—Friday, March 12
6. Indianapolis—Monday, March 22
   Tri Cities—Tuesday, March 23
   Rockford—Wednesday, March 24
   Milwaukee—Thursday, March 25
   North West—Friday, March 26
7. Golden Gate—Monday, March 29
   Los Angeles—Wednesday, March 31

Upon motion properly made, seconded and unanimously carried, the following schedule of visits by directors of the A. S. S. T. for conference with local executive committees following the visit by President Bird was approved. It is as follows:

BORNSTEIN—North West, St. Louis, Rockford
BIDLE—Buffalo, Rhode Island, Hartford, Toronto
GUTHRIE—Milwaukee, Cincinnati, Indianapolis, Tri Cities
HARPER—Lehigh Valley, Philadelphia, Rochester, South Bend
HUGHES—Boston, New Haven, Worcester, Springfield
JEFFRIES—Detroit, Schenectady, Syracuse, Washington
MCCLEARY—Chicago, Cleveland, New York, Pittsburgh

The question of chapter extension was given consideration and the following cities were suggested as possible locations:

Montreal, Chattanooga, Seattle, Denver
Flint, Birmingham, Newark, Dayton
Fort Wayne, Kansas City, Salt Lake City, Columbus
Houston, Omaha, Canton-Massillon, Toledo.

Upon motion properly made, seconded and unanimously carried, the Board was appointed as a committee of the whole to consider possible new chapters and report at a later meeting.

Upon motion properly made, seconded and unanimously carried, the National Office was directed to secure information covering metallurgical education in its various phases from technical schools, class groups and correspondence schools and report at the Hartford meeting.

The meeting of the Board of Directors then resolved into a general meeting with the members of the Publication Committee and received from them a report of their deliberations during their meeting.

After further discussion and an expression of appreciation on the part of the Board for the fine spirit of cooperation, the Board withdrew from the meeting and then met with the members of the Recommended Practice Committee, where a general discussion was indulged in relative to the work and scope of this committee.

Upon motion properly made, seconded and unanimously carried, the sub-committee on the heat treatment of plain carbon and alloy spring steels, the sub-committee on the carburizing of gears and the sub-committee on the carburizing of camshafts, having completed their work, were released from further activity. The Board directed that a letter of appreciation for their excellent work be forwarded to the members of these committees.

Upon motion properly made, seconded and unanimously carried, the appointment of representatives on cooperative committees with other societies was left to President Bird.

Upon motion properly made, seconded and unanimously carried, the treasurer was authorized to take out accident insurance to the amount of $25,000.00 on the secretary in favor of the Society.

Upon motion properly made, seconded and unanimously carried, the meeting adjourned at 6:45 p. m.

FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING FOR THE YEAR 1925

THE official report of Nau, Taylor and Sweringen, certified public accountants, covering the results of their audit of the books of the society is submitted herewith.

This statement again shows a very healthy condition of our finances, the Society working within its income and making substantial increases to its reserves and surplus.

The "Income and Expense Statement" shows an increase of about 15 per cent over our 1924 turnover which indicates a considerable increase in the society activities.

Full details of the audited report are herewith given. The official copy of this report is on file at the society offices and is open for the inspection of any interested members.

EXHIBIT A

BALANCE SHEET

AMERICAN SOCIETY *for* STEEL TREATING

DECEMBER 31, 1925

ASSETS			
CASH			
Cleveland Trust Co.—Commercial Account	$ 7,023.67		
Cleveland Trust Co.—Savings Account	5,302.08		
Equity Savings and Loan Co.—Savings Account	22,432.33		
Union Trust Co.—Savings Account	1,171.62		
Petty Cash	25.00	$ 35,954.70	
INVESTMENTS			
Euclid Village, Ohio, 6% Water Bonds	3,000.00		
U. S. Treasury Certificates (Maturity Value, $2,500.00)	2,235.00		
U. S. Liberty Bonds	28,000.00		
Cleveland Trust Securities Co.—5½% Trust Bonds	10,000.00	43,235.00	
ACCOUNTS RECEIVABLE			
Advertisers	2,390.56		
Convention Exhibitors	781.28		
Miscellaneous—Book Sales, Data Sheets, Service Deposits, etc.	1,237.95		
	4,409.79		
Less—Reserve for Past Due and Doubtful Accounts	912.75	3,497.04	
Accrued Interest—Investments		567.92	
Inventory—Publishing Supplies and Pins, Buttons and Pencils		2,452.65	
Furniture and Fixtures—Book Value		500.00	
DEFERRED EXPENSES			
Buffalo Sectional Meeting	78.55		
Convention, 1926	910.74	989.29	
TOTAL ASSETS			$ 87,196.60
LIABILITIES, RESERVES AND SURPLUS			
Chapters' Share of Dues		1,719.70	
Reserve for Dues Paid in Advance		10,000.00	
Permanent Convention Reserve		20,000.00	
H. M. Howe Medal Fund		3,000.00	
Surplus—Balance, January 1, 1925	28,116.65		
Addition during year—Exhibit B	24,360.25	52,476.90	
			$ 87,196.60

CERTIFICATE

We have made an audit of the books and accounts of the AMERICAN SOCIETY FOR STEEL TREATING for the year ended December 31, 1925, and, in our opinion, the above Balance Sheet—Exhibit A and the annexed Income and Expense Statement—Exhibit B, correctly present its financial

status at December 31, 1925, and a history of its financial transactions for the year then ended, basing the income from dues upon date of cash receipt and other income upon date of accrual, irrespective of date of receipt.

Respectfully submitted,

NAU, TAYLOR & SWEARINGEN,
Certified Public Accountants.

EXHIBIT B

INCOME AND EXPENSE STATEMENT

AMERICAN SOCIETY *for* STEEL TREATING

YEAR ENDED DECEMBER 31, 1925

INCOME			
Advertising		$ 31,991.94	
Membership Dues—Gross		40,161.35	
Exhibitors' Space—Cleveland Convention		44,535.00	
Special Services to Exhibitors—Cleveland Convention		8,253.48	
Admissions—Exhibits and Banquet		4,378.10	
Magazine Sales—Transactions		2,017.43	
Bindery Sales		955.50	
Pins and Buttons Sales		55.00	
Pencil Sales		102.75	
Data Sheet Sales		2,389.03	
Book Sales		716.73	
Reprint Sales and Miscellaneous Income		1,337.18	
Discount on Purchases		477.96	
Interest Earned on Bank Balances and Investments		3,004.54	
Interest Earned on Howe Medal Fund		127.50	
Received from Sale of Capital Stock received for Account previously charged off		7.68	
Total Income			$140,511.17
EXPENSES			
Dues Returned to Chapters		16,039.63	
Support of Chapters		257.12	
Increase of Membership		43.40	
Bindery Expense		685.50	
Pins and Buttons		13.25	
Pencils		72.99	
Data Sheets		3,348.09	
Book Purchases		522.88	
Reprints		389.12	
Library Expense		206.51	
Advertising of Transactions		646.57	
Transactions			
Printing	$ 11,601.85		
Paper and Cover Stock	4,272.23		
Cuts	2,589.26		
Postage	778.14		
Editor's Salary	4,800.00		
Editor's Traveling Expense	260.10		
Editorial Assistance	305.50		
Clerical Salaries	1,755.00		
Advertising Commissions	312.00		
Wrapping	241.67		
Office Rent	725.00		
Stationery and Office Supplies	410.83		
Executive Salary	2,250.00		
Miscellaneous Expense	122.36	30,423.94	
Secretary's Office			
Executive Salaries	3,600.00		
Traveling Expense	1,153.48		
Clerical Salaries	3,218.00		
Office Rent	1,160.00		
Stationery and Office Supplies	802.98		
Postage	1,017.51		
Telephone and Telegraph	332.03		
Auditing Services	165.00		
Miscellaneous Expense	576.27	12,025.27	

President's Office		
Traveling Expense		945.19
Treasurer's Office		
Bookkeeper's Salary	1,200.00	
Office Rent	290.00	
Auditing Services	250.00	
Miscellaneous Expense	103.25	1,843.25
Cleveland Convention		
Executive Salary	3,150.00	
Advertising	7,067.44	
Office and Traveling Expenses	7,813.11	
Exhibit Expenses—Rent, Power and Power Connections, Entertainment, etc.	22,177.27	40,207.82
Directors' Expense		
Traveling Expense	1,090.86	
Miscellaneous Expense	168.12	1,258.98
National Committees		
Salary	3,600.00	
Recommended Practice	493.43	
Finance Committee	215.54	
Nominating	67.59	
Tellers	11.10	4,387.66
Sectional Meetings		
Cincinnati	361.77	
Schenectady	251.56	613.33
Collection and Legal Expense		40.00
Convention Expense—1924		57.07
Discount Allowed		292.71
Bank Exchange		3.59
Howe Medal Expense		375.00
Reduction in Value of Furniture and Fixtures		1,452.05
Total Expenses		$116,150.92
Balance—Carried to Surplus Account—Exhibit A		24,360.25
Total		$140,511.17

BIOGRAPHICAL SKETCHES OF OUR NEW HONORARY MEMBERS

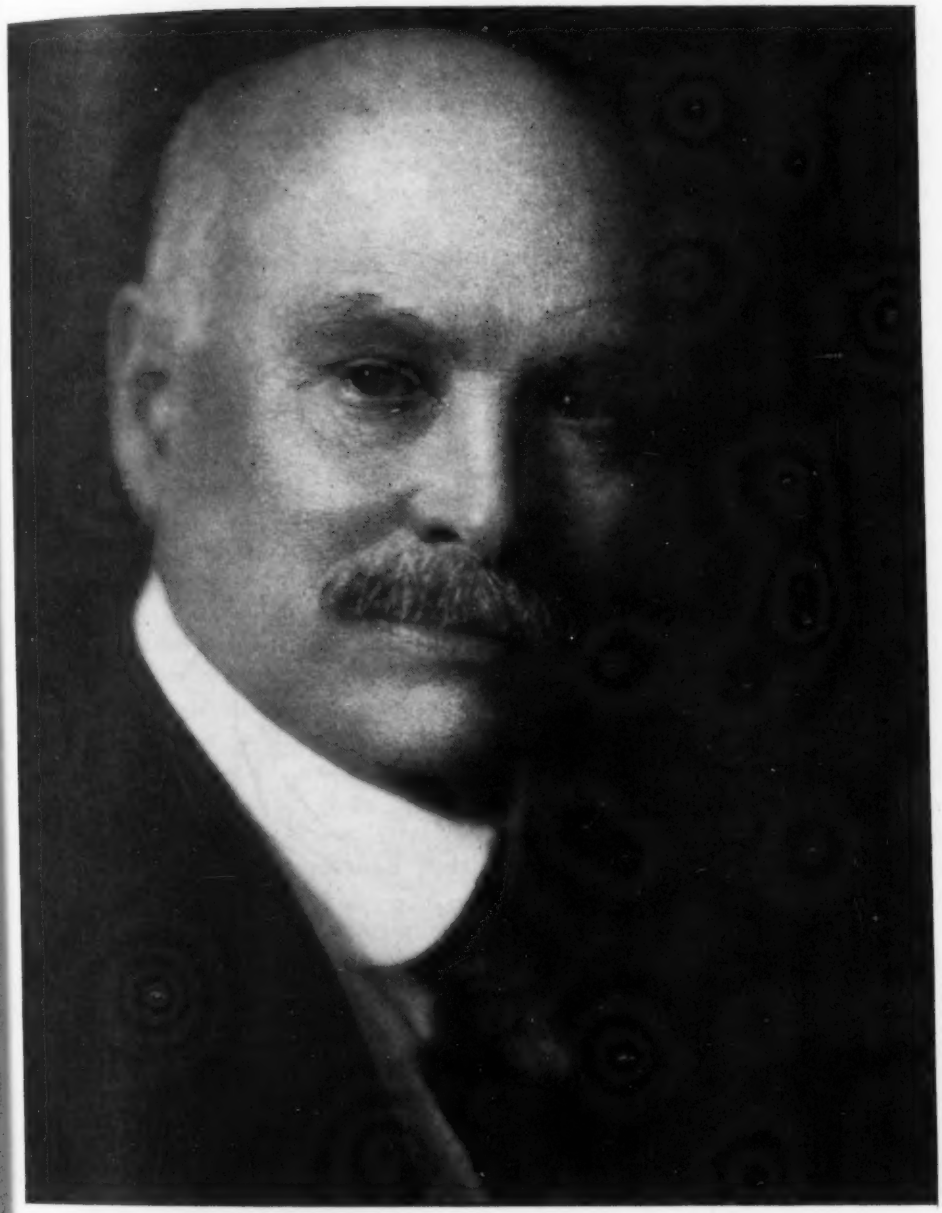
IN the February issue of TRANSACTIONS we had the pleasure of announcing the election of Judge Elbert H. Gary and Charles M. Schwab to honorary membership in the American Society for Steel Treating. The certificates of honorary membership will be conferred upon these two distinguished gentlemen at the eighth annual banquet of the Society to be held in Chicago next September.

BIOGRAPHICAL SKETCH OF JUDGE ELBERT HENRY GARY

"BE FAIR," is the slogan of the Honorable Elbert Henry Gary. Judge Gary's name has come to be synonymous with big business and instantly calls to mind the gigantic steel industry of America. He is, in fact, the genius and guiding spirit of the largest combination of industrial interests under one management ever created by any individual.

The story of how he gained his knowledge and experience which qualified him to build this vast industrial empire is interesting.

His natural instinct for ascertaining the truth about things, led him to



JUDGE ELBERT HENRY GARY

study law. After he had finished his college education at Wheaton, he entered Chicago University and was graduated from its law school with the degree of LL. B. in 1867. That same year he was admitted to the Illinois Bar. In 1882, he became a member of the Bar of the United States Supreme Court. He was for a few years chief deputy clerk of the Superior Court of Cook County, Illinois, and then engaged in the practice of his profession with offices in Chicago. He became one of the leaders

of the bar and served as president of the Chicago Bar Association in 1893-4. He was called upon to hold court in Chicago for a considerable period of his entire service as judge, and presided over a number of important cases in other counties throughout the state. At the time of his retirement from the bar in 1898, he was general counsel for several railroads and industrial corporations, and had a large general practice. His clients included two corporations engaged in the manufacture of steel products.

In 1892 he had charge of the legal work connected with the organization of the Consolidated Steel and Wire Company of Illinois, and of the American Steel and Wire Company, in 1898. That same year he took a leading part in the organization of the Federal Steel Company, which was financed by J. P. Morgan Company. Most of the actual work, legal and otherwise, was done by Judge Gary; and upon completion of the organization he was elected president. He then retired from the practice of law and moved from Chicago to New York.

In 1900 intense competition followed a lessening of prosperity which threatened to cripple, if not bankrupt, the steel industry. It was then that Mr. Morgan, Sr., recognized the ability of Judge Gary as an organizer and executive, and when he, in 1901, financed the United States Steel Corporation, he called Judge Gary to take charge. He is chairman of the board of directors and chairman of the finance committee, and the "chief executive officer of the corporation in general charge of its affairs."

In 1909, The American Iron and Steel Institute was conceived by, and organized under the direction of, Judge Gary. From its inception to the present time he has acted as president, and under his guidance it has grown to be a mighty factor in the industrial world. Much concerning the steel industry is found in his published addresses which were delivered before the Institute.

After a consultation with leading members of the steel industry, Judge Gary called an international meeting of iron and steel manufacturers to be held in Brussels on July 5-6, 1911. Groups of manufacturers from all the iron and steel producing countries including the United States, Great Britain, France, Germany, Belgium, Russia, Austria, Italy and Spain attended. Judge Gary was unanimously elected to preside over the meeting. Citizens of London and elsewhere tendered the delegates banquets and entertained them with features of interest.

The Judge has been a director in more than fifty leading corporations, including railroads, banks, insurance companies, steamship lines, and other industrial concerns, and was also a member of the finance committee or executive committee of many of them. He retired from most of these positions in 1914.

When the United States Steel Corporation desired to build an additional steel plant, Mr. Gary took an active part in locating the site. In 1906 a tract of land comprising nine thousand acres, located in Indiana on the south shore of Lake Michigan, was selected on account of its railroad facilities, its splendid harbor, soil which supplies a heavy foundation, and its proximity to the ore and coal fields. These were the factors which

made this particular location on the Great Lakes advantageous for the production of steel and have resulted in making this plant the greatest steel plant in the world. The city is named in Judge Gary's honor and has now a population of about seventy thousand.

During the World War, Mr. Gary showed his leadership in bringing together all the important steel interests with the result that they provided continuous support, and with no serious delays, all the essential steel requirements for the armies in the field. To carry out this work Judge Gary was appointed, by the secretary of war and president of the Council of National Defense, to serve as chairman of, and to organize, the committee on steel and steel products. This committee co-operated with the war and navy departments in settling questions pertaining to production, distribution, prices, etc., for steel products for war purposes.

Judge Gary, physically, as well as mentally, is a man of splendid poise; somewhat above the average in stature and possessing a kindly and tolerant character. He is a man of vision and creative imagination. He thinks far into the future.

Judge Gary's ancestors were American pioneers who for four hundred years had tilled the soil and upheld the ideals of their country. He was born in 1846 on a farm near Wheaton, Illinois, and here he obtained his early education. He was president of the town of Wheaton three terms and when it became a city he was the first mayor and served two terms. For many years he acted as president of the board of education of Wheaton and was county judge of Du Page County eight years.

He married Julia Emily Graves, June 23, 1869. Mrs. Gary died in Wheaton, June 21, 1902, aged fifty-three and is buried in the Elbert H. Gary family mausoleum in Wheaton cemetery.

On December 2, 1905, he married Mrs. Emma Townsend Scott of San Francisco.

Judge Gary's ability as a lawyer, financier, man of affairs, public speaker and writer has been recognized by various academic honors. His Majesty, the Emperor of Japan, on January 28, 1918, decorated Judge Gary with the Second Class of the Sacred Treasure in gratitude for his valuable services in promoting a better understanding between Japan and America.

One of Judge Gary's hobbies is collecting art treasures. His benefactions include the Gary Memorial Methodist Episcopal Church in Wheaton, erected as a tribute to the memory of his parents; the Young Men's Christian Association building in Gary, Indiana; and the Elbert H. Gary Library of Law, Northwestern University, Chicago.

He is a member of the Society of Colonial Wars, the Sons of the American Revolution, and of many leading social clubs of New York and Chicago.

His home is at 856 Fifth Avenue, New York City.

BIOGRAPHICAL SKETCH OF CHARLES M. SCHWAB

"BOUNDLESS are the opportunities of youth." This is the optimistic attitude taken by Charles Michael Schwab, steel manufacturer,

financier and captain of industry. His passion for wanting to know about everything,—his desire to understand and get at the bottom of things, resulted in his rapid rise to the top.

This future master of men and industry was born at Williamsburg, Pennsylvania, April 18, 1862, but soon after the family moved to the picturesque mountain town of Loretto, where he attended the College of St. Francis. Mathematics became his hobby, and engineering problems especially interested him. His father kept a village store and carried the mail. After the son's college career, he drove the stage between Loretto and the railroad station, five miles away.

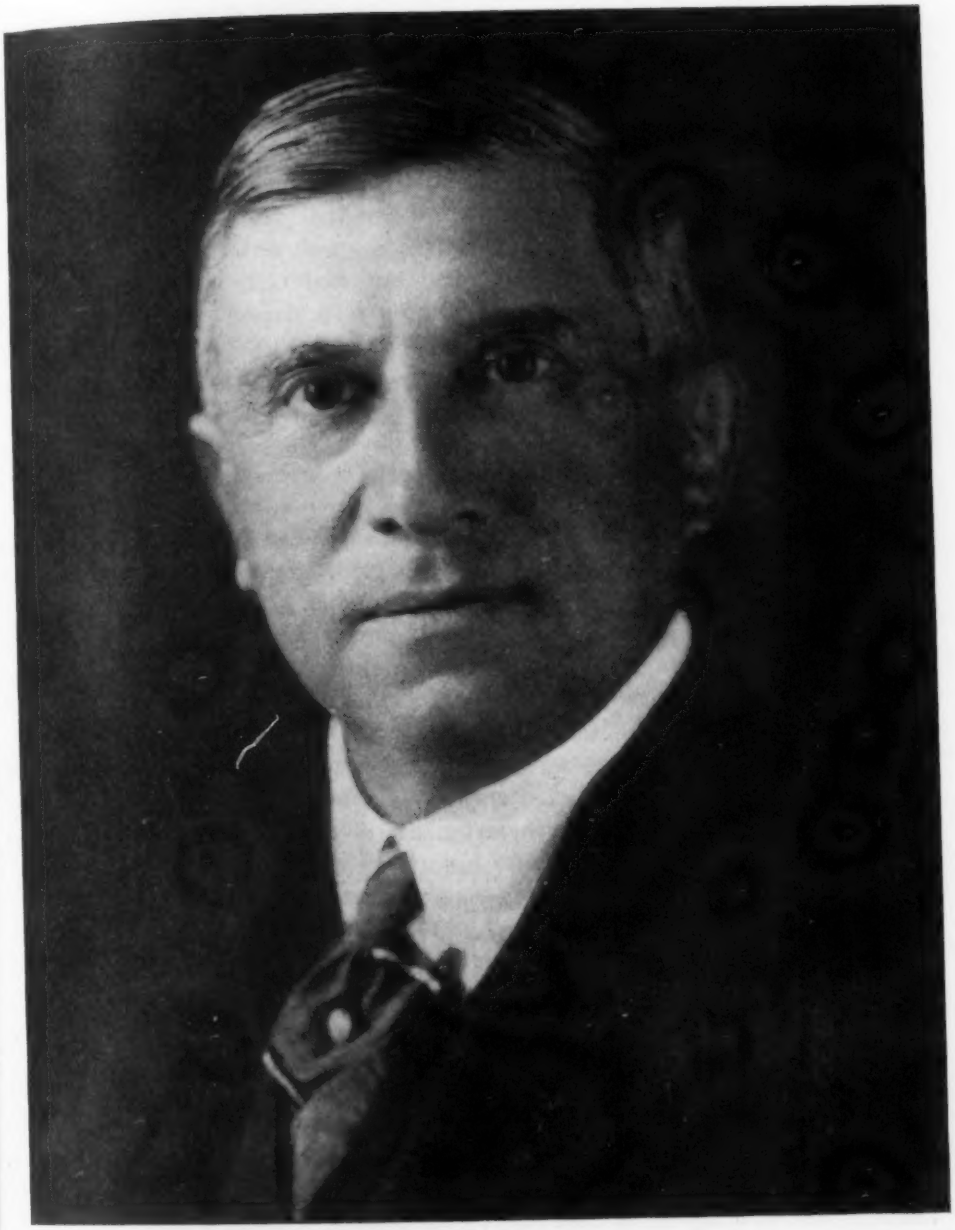
But soon the family went to Braddock and the son became a clerk in a grocery store. Although he had higher ambitions, he did his best smilingly and made many friends. But the ceaseless activity of the steel works fascinated him. He longed to become a part of it,—identified with its growth and progress. One day the glorious opportunity arrived! It was in the person of the remarkable genius and leader of men, Captain William Jones, a patron of the store. Courageousy, one day, the lad asked him for a place in the mill.

"Can you drive stakes?" asked Captain Jones. "I can drive anything," replied the lad. So much was the superintendent of the Edgar Thomson Steel Works impressed with his intelligence and enthusiasm that the next day the grocery clerk had a job driving stakes at one dollar per day in Carnegie Brothers' Mill. Steadily he was assigned tasks of greater responsibility which he performed cheerfully and studiously. After his day's work he specialized in the study of chemistry and applied its principles to the manufacture of steel. His experiments in testing the strength and quality of steel revolutionized the steel industry. He introduced processes of manufacture that cut down costs and brought up profits.

So well did he perform his tasks that within seven years after entering the Edgar Thomson plant, he became its superintendent. Thus, after the tragic death of one of the greatest steel men in the world, Mr. Carnegie sent him to Braddock to succeed his old master, Captain Jones; gave him a $50,000 interest in the business and a salary of $50,000 a year. This was the most rapid rise for a boy on record and he accomplished it by understanding his own job and then studying the one higher up.

In 1892, when the Homestead Steel Works was opened after the strike, Mr. Schwab was made superintendent. The problem existing in the management of men was so ably handled by the tactful Mr. Schwab, that in 1896 he was made a member of the board of managers of the Carnegie Company and elected its president the following year.

Offers of huge salaries abroad did not tempt Mr. Schwab and his loyalty so impressed Mr. Carnegie that he made a new contract with him for a minimum salary of $1,000,000 per year. This was the contract that annoyed Mr. Morgan, Sr., when the Carnegie interests were capitalized at $1,000,000,000. Mr. Morgan hesitated.—"What's to be done?" "This," answered Mr. Schwab, and he tossed the contract into the waste basket which had netted him $1,300,000 for a year's work. This was the time when rivals of the powerful Carnegie Corporation saw how futile



CHARLES MICHAEL SCHWAB

their endeavors were and keen business men realized that the purchase of the Carnegie interests was necessary to their success. Mr. Carnegie named a price. Mr. Schwab acted as intermediary and obtained the price which had once been regarded as absolutely prohibitive. Mr. Carnegie had accepted a half billion dollars for his share and was out of the steel business. Mr. Schwab was now head of the United States Steel Corporation at the age of thirty-nine. After holding the presidency for three years, he resigned—suddenly—giving up a salary of $100,000 per year. This was

said to have been caused by a clash of ideas, a hampering of his plans. To some it seemed the end of his phenomenal career, but after a few years vacation his most stupendous effort began.

In 1908 he bought the bankrupt Bethlehem Steel Works from the United States Shipbuilding Company and backed it with every dollar he had. He selected fifteen young partners out of the mill on a profit sharing basis.

A trip to Russia resulted in an order for an entire navy. During the World War the output of Bethlehem in war materials was in excess of the great Krupp Works at Essen. Allied orders to the amount of $400,000,000 poured in.

Mr. Schwab enjoyed taking a risk. To him, it was part of the game. A risk of $15,000,000 for the trial of the invention of the Gray method of manufacturing structural steel, proved a winner. It made Bethlehem supreme! Thus, defunct Bethlehem became a close second to the United States Steel Corporation.

The year 1914 marked the climax for Mr. Schwab. The World War was in progress. A hasty summons from Commander-in-Chief Lord Kitchener sought him in conference in London. The hero of Khartoum had met Mr. Schwab when he visited America and knew the capacity of Bethlehem for making war necessities quickly. The hurried trip resulted in getting a huge contract for Bethlehem from the War Office of the British Empire.

Soon after Mr. Schwab's return to America, submarines were speeding under the Atlantic, and Bethlehem was producing a million shells every month. The United States Government placed orders with Bethlehem amounting to $500,000,000 for war munitions and ships.

In April, 1918, Mr. Schwab was made director-general of the Emergency Fleet Corporation; his biggest job and smallest pay, one-dollar-per-year. When labor troubles threatened, Mr. Schwab by his irresistible energy, patriotism and strong personal magnetism amicably overcame all objections and every man in the shipyards put forth his best efforts to answer the vital question: "Where are the ships coming from?"

When it became imperative to send 300,000 men overseas every month with corresponding cargoes of supplies and munitions, he feverishly set to work to accomplish this gigantic task.

Mr. Schwab is a maker of men, not merely workers. He inspires them through his own splendid character, enthusiasm, loyalty and fidelity to do their best work and give expression to their noblest impulses. He wants men to work with him, not for him.

Like all geniuses, Mr. Schwab cares little for wealth.

"I work," he said once, "just for the pleasure I find in work, the satisfaction there is in developing things, in creating."

"To my mind," says Mr. Schwab, "the best investment a young man starting out in business can possibly make is to give all his time, all his energy to his work—just plain, hard work."

Mr. Schwab is a director in many banks and commercial institutions,

and in recognition of his splendid contributions to society many colleges have bestowed upon him honorary degrees.

At the age of twenty-one, Mr. Schwab married Emma Dinkey, in 1883. To her he attributes much of the success that has come to him. It was she who so nobly inspired him to do and dare.

He is exceedingly philanthropic. He built a Catholic church in Loretto and another at Braddock; established an industrial school at Homestead, and erected a magnificent home for crippled children on Staten Island.

Music is his hobby. A wonderful pipe organ was installed when he built his superb $8,000,000 French chateau on Riverside Drive which is said to be one of the finest pieces of architecture in America.

A MESSAGE FROM THE PUBLICATION COMMITTEE

THE Publication Committee does its work quietly. It is the duty of this committee to pass upon the merits of manuscripts submitted for publication in TRANSACTIONS and the only public manifestation of its efforts is reflected in the type and quality of the papers selected.

During 1925 this committee reviewed 87 manuscripts, most of which were accepted by them for publication. All of these manuscripts were reviewed by at least one of its members; some were read and passed upon by two members, and a few had even further consideration.

The committee is putting forth its best efforts to raise the standard of TRANSACTIONS from year to year and is at the same time endeavoring to please the diversified tastes of its readers. It would not be fair, for instance, to the practical members to publish too many highly technical papers, in spite of the fact that some 27 per cent of the membership might be classed as technical (20 per cent metallurgists, 4 per cent chemists and 3 per cent instructors and students). On the other hand, it would not be fair to the technical men to publish too large a proportion of so-called practical papers in spite of the fact that 10 per cent of the membership includes "heat treaters" and 12 per cent salesmen. The remainder of the members must also be kept in mind, namely, 3 per cent proprietors, 4 per cent presidents, 2½ per cent vice-presidents, 10 per cent managers, 10 per cent superintendents and 11 per cent engineers, with 10½ per cent classed as miscellaneous. It will easily be seen that the proper balancing of our TRANSACTIONS is rather difficult.

The Committee has from time to time received suggestions that

there have not been enough practical papers in TRANSACTIONS. Much time and effort has been expended by this committee in an endeavor to find an acceptable definition by which a practical paper may be distinguished from a technical one. In some cases there would be little doubt as to the classification of an individual manuscript, but in other cases some members would class a paper as technical which others would call distinctly practical. Where shall the line of demarcation between a practical paper and a technical paper be drawn? The committee has come to the conclusion that it is impossible to draw a sharp line between these two classes, and that what is considered a technical paper today might be classified as a practical paper tomorrow. The thought has been expressed by a member of the committee that one might define a practical paper as one which required no thought in its reading, but is this type of paper the kind desired by most of our membership? Many so-called highly technical articles contain practical suggestions. If you doubt this, read the paper by Messrs. French and Klopsch, presented at the Buffalo Winter Sectional Meeting in January, 1926.

It may interest you to know that the editor of TRANSACTIONS recently made an analysis to determine the amount of space which had been devoted to practical papers, technical (or theoretical papers) and semi-practical (or semi-technical) papers in the TRANSACTIONS for the year 1925 (Volumes VII and VIII). According to his appraisal it was found that of a total of 1240 pages of the TRANSACTIONS (omitting such items as Technical Abstracts, Patent Reviews, Questions and Answers, Chapter News, and General Items of Interest), 29 per cent (359 pages) were technical, 16 per cent (194 pages) were semi-technical, and 55 per cent (687 pages) were practical. This appraisal was checked very carefully by the entire Publication Committee at its all-day meeting in Buffalo in January, and in spite of some individual differences of opinion as to classification, it was decided that the editor's analysis was substantially correct. Under the circumstances it would appear that the practical papers are by far in the majority, and to those who believe otherwise our committee sends the message: "Read your TRANSACTIONS! Read all the TRANSACTIONS!"

PROF. H. M. BOYLSTON,
Chairman of Publication Committee.

MARCH TRANSACTIONS

WITH the present issue of TRANSACTIONS one-half of Volume 9 has been completed with a total number of 522 editorial pages. In these three issues (January, February and March) there have been published 20 articles occupying a space of 400 pages. These are exclusive of editorials, news of chapters, abstracts of technical articles, patent reviews, items of interest, etc. Five of these papers might be classified as technical, one as semi-technical or semi-practical, and fourteen as practical.

The March issue contains 114 pages devoted to the publication of eight papers, two of which are of the technical type and six of which are of the practical type. The two technical papers occupy 28 pages and the practical papers occupy 86 pages.

Three of these papers were presented before the Cleveland Convention of the society last September and five of them were written for publication in TRANSACTIONS. One papers deals with the cutting of wood and metals, three with heat treatment, and one with the standardization of testing machines used in the testing of metals.

The paper on cutting presents a short description of the mechanics involved in the cutting of wood and metals; another deals with a comparatively new method of the heat treatment of metals by employing one of its physical properties (expansion) which occurs when passing through the critical ranges. A third paper pertains to the cost of heat treating automobile parts, the fourth with a shop method for verifying or standardizing the Brinnell-type of hardness testing machine; a fifth deals with an elementary discussion of the manufacture of wrought iron, gray iron and semi-steel; while the sixth is a non-technical discussion of the causes for the warping and cracking of metals during the process of fabrication and heat treatment.

The two technical papers contained in this issue of TRANSACTIONS are of great importance, and while they are classified in this discussion as technical, they, no doubt, will have a wide influence upon many practical problems dealing with the heat treatment of metals and the effect of various combinations of chemical elements in the heat treating of metals.

It will be seen from this brief analysis that the ratio of practical to technical is decidedly in the favor of the practical. By

way of suggestion, may we say that there has been an average of over 55 per cent of TRANSACTIONS space devoted to practical papers during the past fifteen months.

It would seem that these papers, diversified as they are, will make wide appeal and that every reader may find material to his liking.

THE details of arrangements for the Spring Sectional Meeting to be held in Hartford, May 20 and 21, 1926, are now well under way, and the members of the Hartford Chapter insist that this meeting will be the best regional gathering which will have been held by the Society.

The committees on arrangements realize that they have a high mark to shoot at, but we are sure that when they start out to do a thing they succeed.

The committees are as follows:

Program Committee
L. A. Lanning
Entertainment Committee
J. J. Curran and Ralph M. Johnson
Plant Inspection and Transportation
R. F. V. Stanton, B. M. Crum and G. J. Comstock
Hotel, Registration and Information
A. H. d'Arcambal, H. I. Moore, C. W. Atwood and G. S. Longley, Jr.
Securing Local Attendance
R. W. Woodward
Publicity
W. D. Fuller
Finance
C. A. Allen and E. D. Lambert

Future Meetings

SPRING SECTIONAL MEETING—Hotel Bond, Hartford, Connecticut, May 20 and 21, 1926.

ANNUAL CONVENTION AND EXPOSITION—Municipal Pier, Chicago, Illinois, September 20-24, 1926.

WHY METAL WARPS AND CRACKS

By John F. Keller

Abstract

The author of this paper has presented and has discussed in simple terms, the various factors which come into play in causing iron and steel bodies to warp or crack when subjected to heat.

He illustrates by means of diagrams and experiments the manner in which these factors cause the failure of metallic bodies. Several photographs are included which show the effect of external strains.

IN an effort to furnish service to the industries of the state of Indiana in the form of conferences, plant visitations, short courses, evening classes, correspondence, etc., it has been found that the various problems submitted for solution in the above phases of the subject lead to the conclusion that the average technical and nontechnical operator in the metal industries does not, as a rule, seriously consider certain phases of the subject that play an important part in the causes for the warping and cracking of metals. In order, therefore, that due consideration may be given to these problems from the angles hereinafter suggested, certain facts are presented which have been collected from observation and experimentation.

There are many metallurgical and mechanical factors that are and have been attributed as the causes for the warping and cracking of metals. However, we propose to eliminate every factor except that of the unequal heating and cooling of metal and propose to show by drawings and suggested shop experiments, etc., that certain deformations take place due to this factor, and that such deformation is one of the important causes for the warpage and cracking of metals. It was found during the preparation of this paper that the few articles written on the subject have the common fault of being written in a highly scientific style, thus making it difficult for the average engineer or shop man to obtain a concrete "picture" of the ideas involved. It is, therefore, our desire to present the subject from a shop standpoint, so that the average engineer, production manager, superintend-

A paper presented before the Cleveland Convention of the Society, September, 1925. The author, John F. Keller, is Steel Specialist, engineering extension department, Purdue University, Lafayette, Indiana.

ent, foreman, and operator may be able to interpret and experiment as suggested, thereby visualizing the causes for "deformation." Technically trained men, however, will find some points of interest that may assist them in brushing up on this important subject. In order that the reader may have a clearer conception of the cause for "deformation" it will be necessary to seriously consider the following physical properties:

1. All ferrous and nonferrous metals have a fairly definite strength at atmospheric temperature depending, of course, upon their chemical composition, freedom from metallurgical and mechanical defects, methods of fabrication and heat treatment.

2. Upon the reheating of such metal, particularly iron and steel, the strength remains fairly constant in all steels until a temperature of about 650 degrees Fahr. is reached. The strength of cast iron also remains fairly constant until a temperature of 800 to 900 degrees Fahr. is reached, at which temperature the strength decreases proportionally with increase in temperature to its highest transformation point, at which point we may expect a low minimum of strength due to a change in state. When the transformation is completed, the metal regains about 10 per cent of its original nonheat-treated strength, but again diminishes in strength proportionally with increase in temperature to zero at its melting point. Conversely, in cooling, the reversal of the above takes place with the exception that there is not such an extreme loss of strength in cooling through the critical range.

3. It is a known physical law that upon heating a solid body, the body expands in all directions and this expansion is proportional to the increase of temperature. Likewise the body contracts to its normal dimensions upon cooling, providing, however, there is no *resistance* to the normal expansion of the body when being heated, or to its contraction to its normal dimensions when being cooled.

4. It is also a known law that *"a force follows the path of least resistance,"* therefore, if there be *sufficient resistance* to prevent the normal increase in the dimensions of any part of a metal body being heated, a "deformation" must take place due to this *resistance,* and loss of strength due to increasing temperatures. Therefore, owing to its plasticity, the metal will flow and follow the path of least resistance, providing, however, that the metal is of sufficient cross-section to withstand compressive forces.

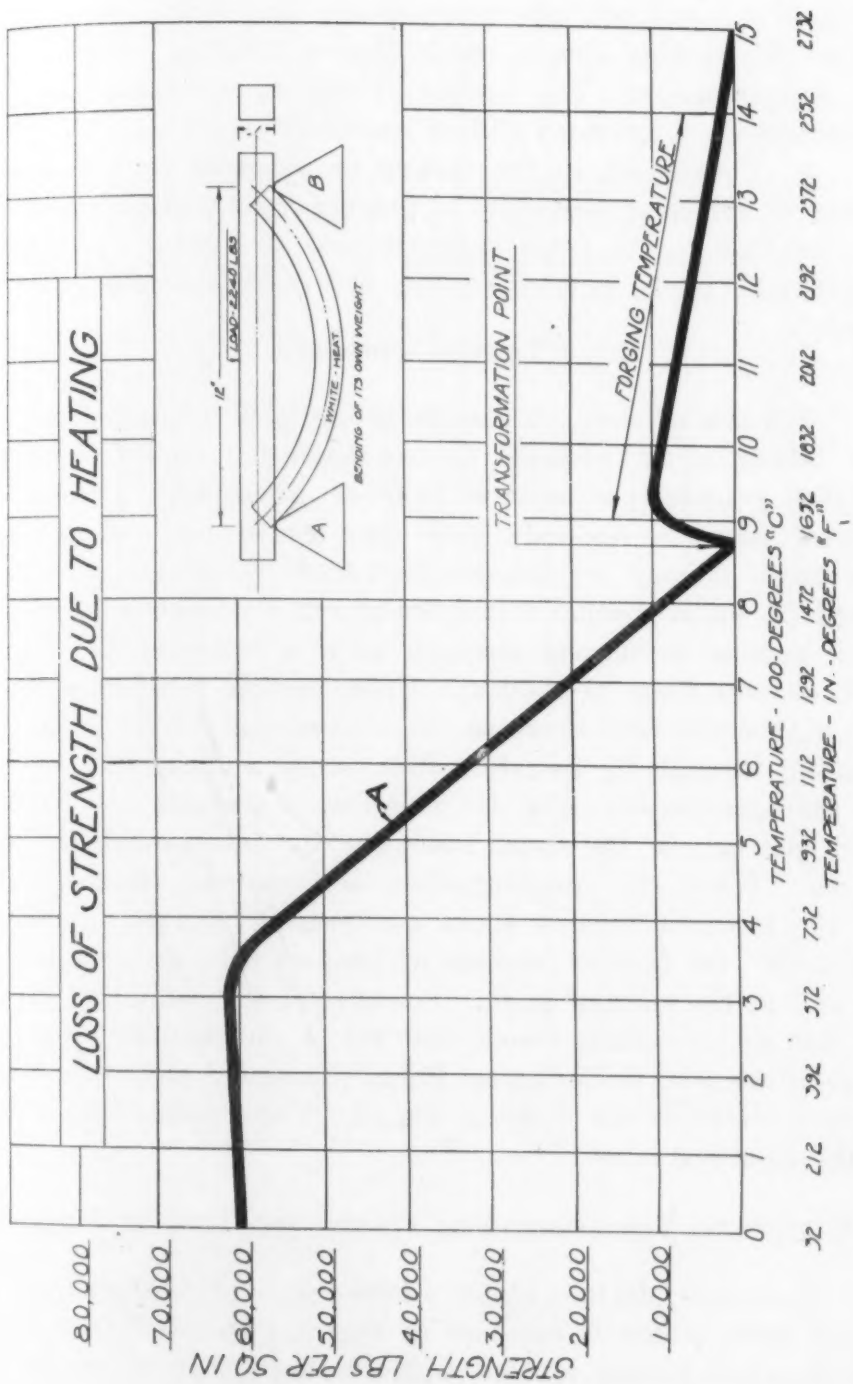


Fig. 1—Diagram Showing the Loss of Strength of Steel Due to Heating.

Otherwise column-action will take place. "Deformation," as above indicated, is known in shop terms as "upsetting."

5. In the localized heating of *thin* sections of metal, "de-

formation'' will not take place to any appreciable extent in the form of upsetting, due to the folding or bending. This is known as *column-action*. The folding is due to resistance preventing extension in dimensions and to loss of strength.

6. Conversely, in the cooling of a heated metallic body, if there be sufficient *resistance* to prevent the expanded metal from contracting to its normal dimensions, *elongation* or stretching must take place, particularly in the portion of the metal last cooled.

Loss of Strength

The loss of strength may be graphically illustrated in Fig. 1 by taking as an example a steel having a tensile strength of 60,000 pounds per square inch at atmospheric temperature. When heat is applied, and the temperature of the mass increases, it may be noticed that there is no loss of strength until the metal reaches a temperature of 650 degrees Fahr. Cast iron retains its normal strength until a temperature of 800 to 900 degrees Fahr. is reached. Upon further increase in temperature, the strength decreases to a minimum while the metal is passing through its transformation range, indicated by the drop in the curve to zero, Fig. 1. This loss of strength occurs only to such portions of the metal heated to the transformation temperature. When the transformation is completed in any portion of the metal it regains about one-tenth its normal atmospheric strength. On further increase of temperature, strength decreases to zero at the melting point. Conversely, on cooling, the reversal of this action occurs, except that the A_r or recalescence point is lowered some 50 to 75 degrees Fahr., illustrated in the heating and cooling curve at the right of Fig. 2. These points will be more fully explained later.

Expansion, Transformation Points, and Loss of Strength

A simple device which illustrates and demonstrates the above three points is outlined in Fig. 2. If a sufficient amount of electrical energy is used to heat the wire to a temperature above its transformation point all three points may be studied. With the first application of heat, the wire will expand in length, causing the arm (a) to move to the right and in proportion with increase of temperature (evidence of expansion).

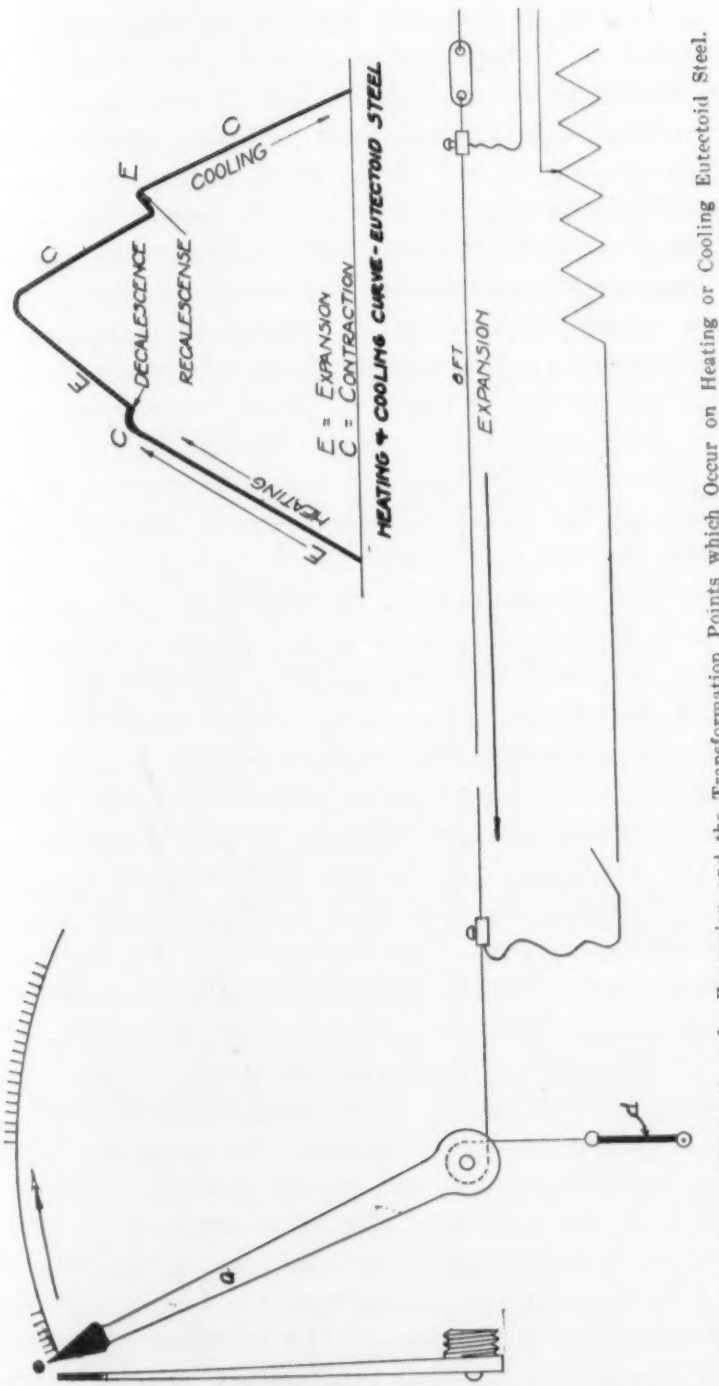


Fig. 2—Diagram Illustrating the Expansion and the Transformation Points which Occur on Heating or Cooling Eutectoid Steel.

When the wire reaches a temperature at which transformation take place (a change in state) the arm (a) will stop for an instant and move back to the left a short distance, even though the current is passing through the wire. This point of transfor-

mation is known in the heat treating of steel as the "critical temperature" or "decalescence point," illustrated in the heating and cooling curve of Fig. 2. The retardation or contraction of the wire indicates a decrease in volume. It also indicates the temperature at which the metal changes its state from that of an aggregate, "pearlite" (soft steel) to "austenite," a solid solution of iron and carbon (hardened steel, if quenched quickly). Upon further increase of temperature the wire will continue to expand in length in proportion to the increase in temperature and is clearly indicated by a forward movement of the arm (a).

When the current is shut off, the wire contracts at a normal rate until the "recalescence point" (relighting) is reached. At this point the arm (a) stops and moves forward about 2½ times the distance of the previous retardation in heating (evidence of considerable increase in volume).

When the transformation is completed, the metal has returned to its former state (soft steel). Upon further cooling the wire again contracts until atmospheric temperature is reached. We would assume that the metal under the above conditions would return to its original length and that the arm (a) would likewise return to zero position. A remarkable fact, the arm (a) will not return to its normal position because of the fact that the small rubber band, marked (d), had sufficient *resistance* or tension to elongate or stretch the wire while the metal was passing through its transformation points. The wire used in this experiment had a tensile strength of over 200,000 pounds per square inch at atmospheric temperature, but when heat was applied there must have been considerable weakness in the metal at some temperature in the heating operation, in order that the wire could elongate with such a slight amount of tension as that exerted by the rubber band. Theoretically, we should expect a weakness, or in fact, a discontinuity in any portion of the metal reaching the temperature at which transformation takes place because of its change in state.

The following simple example might help to illustrate the change in state that takes place at the transformation points and the loss of strength or discontinuity caused thereby.

Let us assume that the structure of a piece of steel would be composed of an aggregate of granules of white marble and granite (ferrite and pearlite in low carbon steel, or pearlite and cementite in high carbon steel), and these grains held in place by cement as a

binder. Let us also assume that it would be possible to heat such a mass to a temperature (critical temperature or transformation point), at which point this coarse aggregate would break up into a fine state and thoroughly mix and combine one with the other and with the cement, without the material changing its shape, thereby forming a solid solution (austenite in iron and steel). If we can conceive of such a possibility then we have a fair conception of the change that takes place when iron and steel are heated to their highest transformation range. Is it not conceivable that there must be a discontinuity at that point and, if so, how could the

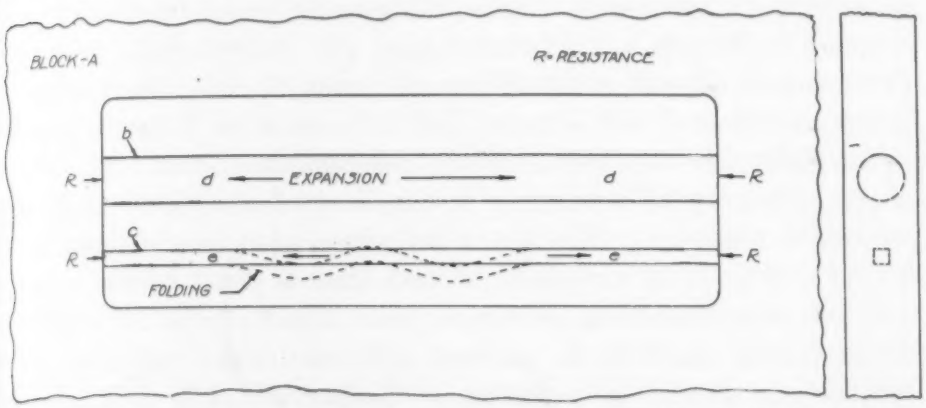


Fig. 3—Illustrating the Effect of "Resistance" upon the Partial Heating of Metal.

metal have strength? This, then, is the probable cause of loss of strength at the A point, as indicated in the curve of Fig. 1.

The Effect of Resistance to Expansion in Length

It is a well known physical law that if heat is applied to a solid body, expansion in all directions takes place. It is also a well known fact that when heat is withdrawn from such a body, contraction takes place accordingly. In the above case it is assumed that the mass has freedom to so expand or contract. However, have we stopped to consider the effect of resistance to the above conditions of expansion or contraction?

In the designing of metal structures, provision is always made to allow perfect freedom for metal parts to expand and contract when there may be appreciable changes in temperature. Open joints in railroad tracks, expansion joints on steam pipes, etc., are good examples of this point.

In the localized heating of metal this phase of the subject is rarely given serious consideration. Therefore, in order to study

and visualize the effect of "resistance" upon the partial heating of metal, the drawing and simple experiment, shown in Fig. 3, have been prepared for the purpose.

Block A, Fig. 3, represents a soft ductile steel block of sufficient strength to resist the lengthening of the bars placed within the slot when such bars are partially heated. However, any other type of "resistance" of sufficient strength will answer the purpose for this simple experiment.

Let us study the action of such an experimental bar placed in the position as indicated at (b), and locally heated between the points (d d). Upon the first application of heat, the bar (b) will expand in length at a definite rate, per degree Fahr., and this extension in length without loss of strength will continue up to a temperature of 650 degrees Fahr. for steel and 800 to 900 degrees Fahr. for cast iron. With these points in mind, something must happen. It is simply a question of the survival of the strongest material. We are wondering what would happen to block A, Fig. 3, if composed of cast iron or hard brittle steel?

We are assuming, however, that block A is of sufficient strength and ductility to prevent deformation or rupture. With further increase of temperature of the bar (b), Fig. 3, the heated portion becomes weaker in proportion to the increase in temperature illustrated in the curve of Fig. 1. The bar (b) should also increase in length but, owing to the *resistance* of R R., block A, and to the loss of strength of the metal, *deformation* takes place in the heated portion. In shop practice, we would say that the bar was upset, therefore, shortened its length.

Allowing the bar (b) to cool to atmospheric temperature, the metal will return to its normal *deformed* length, because there is *no resistance* to prevent normal contraction, consequently, the bar, when cold, will be too short in length because *deformation* has taken place, due to the *resistance* of R R. Block A prevented its expansion in length, and this upset bar will not, of course, fill the space it formerly occupied. It is assumed, in such an experiment, that the bar (b) is of sufficient diameter or cross section to prevent column-action.

Column-Action

In the localized heating of bar (c), (Fig. 3), similar to that of bar (b), we have an entirely different problem. Owing to the

small cross-section of the bar (c), deformation in the form of folding or buckling will take place, the buckling will be due, of course, to the resistance of block A preventing extension in length. When cold, the above condition remains, due to the previously deformed section and to the fact that there is no resistance to contraction in the deformed state.

The Effect of Resistance in Cooling

In the preceding paragraph we have pictured the effect of *resistance* upon local heating of metal. Therefore, to emphasize the point and to study the problem from the opposite angle, we will observe the effect of *resistance* in the cooling of metal. We have outlined a drawing and simple experiment to illustrate the point, Fig. 4. It is assumed that block B is composed of a ductile steel of sufficient strength to resist the lengthening or the contraction of bar (a), when this bar is heated and cooled between the points (b b). It is important that the bar fit snugly and make contact at points R and R^1. By applying heat to bar (a) between the points (b b), we will have an exact duplication of experiment in Fig. 3, in that when heat is applied, the resistance of R prevents the extension in length of bar (a). (It would be interesting from a foundry standpoint to make the above experimental section out of cast iron and prove or disprove that deformation in the casting actually takes place.)

However, in cooling we have an entirely different problem from that of the experiment in Fig. 3. In that case the metal had freedom to return to its normal deformed length. In this case, however, the *resistance* of the points R^1 in Fig. 4 prevents the metal from contracting or shortening its length. Under these conditions what would be the condition of the bar when cold?

(1) We must consider that the center of the bar (a), between the points (b b), would be the last portion to cool, because of the conduction of heat into the supporting block from each end contact, consequently, the greatest stress or pull would be concentrated at that particular point.

(2) If bar (a) were composed of cast iron, rupture would undoubtedly take place at the point of greatest stress, and particularly in the part last cooled, indicated in the center figure of Fig. 4. The distance or space between the points of rupture may

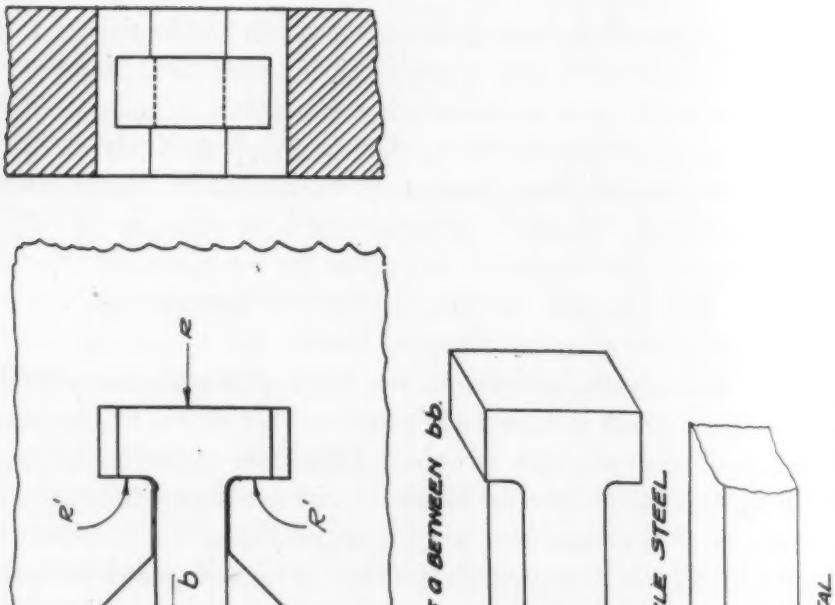


Fig. 4—Diagrams Illustrating the Effect of Resistance in Cooling.

indicate the amount of deformation that previously took place upon heating.

(3) If bar (a) were composed of a soft ductile steel, deformation in the form of elongation would take place in the portion

last cooled, as illustrated in lower figure of Fig. 4. If failure or rupture should not occur under such conditions, unusual stresses would be concentrated in the direct center of the bar. Such stressed material will eventually fail when an excess load or stress is applied. If tapped with a hammer while held in suspension in the block, the metal will resound like the head of a base drum, due to the extreme tension under which it is held in the block. These simple experiments illustrate the causes for many failures in fabricated metal parts and especially in cast material.

Reduction in Diameter of Mass Due to Resistance

The next illustration and experiments are suggested for the purpose of discussing a factor that may be a contributing cause for numerous failures in castings, boiler plates, fabricated machine parts, etc. Like the preceding experiment, we again select a block of sufficient strength, to prevent the increase in diameter of the test block. Block C, Fig. 5, has a hole in the center, into which is tightly fitted a machined plug (a).

Let us assume that it would be possible to heat plug (a) without excessively heating block C. Upon the first application of heat to the plug, it should increase in diameter in proportion to increase in temperature up to 650 degrees Fahr. During this period of increase in size, the plug would exert abnormal stresses upon the block C but, owing to its strength and ductility, would probably resist deformation and rupture. If, however, the block were composed of cast iron or hard brittle steel, rupture would undoubtedly occur under such a stress.

Upon further increase in temperature the plug (a) loses its strength, therefore the *resistance* of block C would act as a compressive tool upon the soft plastic metal, and *deformation* would take place. But where is the excess metal going? Naturally, the semi-plastic metal will move under the pressure of R and flow in a horizontal plane, because this is the "path of least resistance," therefore, the plug will elongate as indicated at cross-section (a′) and (b, b).

Upon the slow cooling of the plug (a) to atmospheric temperature, it may be likened to the experiment suggested in Fig. 3, in that there is no *resistance* to prevent normal contraction, consequently, no further deformation takes place. However, the plug (a) will be reduced in diameter and in proportion to the compres-

REDUCTION IN AREA DUE TO DUCTILE METAL

Fig. 4—Diagrams Illustrating the Effect of Resistance in Cooling.

sion of R, with a corresponding increase in length. It would be well to remember in this and all other problems of this character, that metal occupies a larger space in this universe when hot than when cold, therefore the plug (a) will not fit the original space when cold.

To further emphasize the point above suggested, let us con-

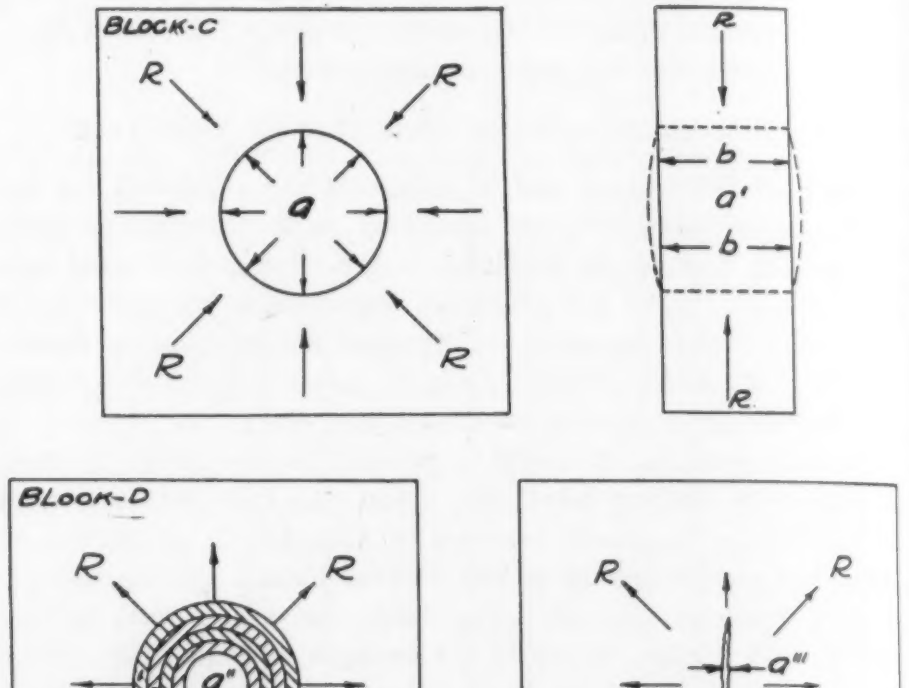


Fig. 5—Reduction in Diameter Due to Resistance.

sider block C as a solid without a hole in the center, and let us assume that it would be possible to heat the center of the block in a manner similar to the heating of plug (a). We would have an exact duplication of the conditions that existed in the heating of the plug, but, on cooling, we would have an entirely different condition of affairs. In fact, the cooling of the metal would be similar to the cooling of bar (a) in Fig. 4. In this problem we must consider that when metal is heated it increases in

volume in proportion to increase in temperature, therefore occupies a larger space than when cooled to atmospheric temperature. Consequently, if 12 inches of the block were so heated above its critical range, it should fill a space of 12⅛ inches, but due to R it only occupies a space of 12 inches while hot, therefore, if the metal had freedom to contract, similar to that of plug (a), it would occupy a space of almost 11⅞ inches, but due to resistance it must still occupy a space of 12 inches. The resistance of block C in this case is reversed, due to the cold block acting as a tension device and, therefore, creating a pull upon the heated metal trying to contract. Let us consider the order in which the metal will cool to atmospheric temperature. The mass will cool from the outside diameter of the heated portion to the center by conduction of the cold block C, that is, the center of the mass will be the last to cool.

This point is illustrated in Fig. 5. The heated portion of block D is divided into a series of rings marked 1, 2, 3, 4, 5. Ring Nos. 1, 2, 3, 4 will cool in this order and should become smaller in diameter, but due to the resistance of block D and due to the cohesive quality of our ductile irons and steel, they are held from reducing in diameter. Consequently, the center would be the last portion to cool, therefore, the No. 4 ring in cooling develops an excessive tension or pull on No. 5 or a″. If the metal does not rupture or crack from the above stress when cold, it will leave such parts in excessive tension similar to that of tuning a base-drum head. In this case, however, the tension is not uniformly distributed over the entire mass, but concentrated in the portion of the metal last cooled, the center.

From these simple experiments we may be able to trace the reasons why such localized heating may be the cause of abnormal stresses in boiler and other plates of steel. Such stresses may also be the direct cause of fatigue rupture of such plates, especially while under tension, and the cracking of castings and other hard or brittle metal.

To the man with an analytic mind who will carefully examine the rupture, it will be evident that the size of the opening in the crack (illustrated in Fig. 5 at a‴) may partially denote the degree to which the metal has been deformed plus the amount of stretch or elongation that may have occurred before rupture took place in soft ductile metal. In hard or brittle metal the open-

ing in the crack will be fairly indicative of the amount of deformation previously taken place upon heating.

Repair Welding

Ruptures occurring similar to the one illustrated in the lower right hand corner of Fig. 5 may be successfully welded by oxy-acetylene torch or electric arc, providing it is possible for the welder to preheat the portion of the metal that would act as a *resistance* to normal expansion of the parts to be heated for welding purposes. In similar cases of rupture, as indicated in Fig. 5, local preheating above and below the rupture would cause the crack to open, and while in this state welding can be successfully accomplished providing, of course, that the two heated points indicated be kept at a red heat until the welding operation is finished.

If provision is not made to remove the *resistance* failure may occur. A simple experiment to demonstrate this point would be to attempt to weld the ruptured cast-iron test piece previously broken by slow cooling, if held in the block to prevent expansion or contraction, Fig. 4. In this case both ends of the bars would be held in a fixed position, thus preventing any movement due to expansion or contraction. Similar conditions exist in attempting to weld a rail joint where both ends are rigidly fixed and no provision made to allow freedom of expansion or contraction. The stresses induced would be in proportion to the length of section preheated, the temperature of such preheating, and the volume of metal poured around the welded joints.

To further illustrate the above phase of the problem, let us consider the unequal cooling of castings in the foundry.

Cooling of Castings

It is a known fact among molders and foundrymen that if provisions are not made to equalize the cooling of castings, warpage or cracking takes place, and such a condition of affairs, they say, is "due to shrinkage." The effect of compressibility upon the soft, weak metal is not, as a rule, seriously considered. In fact, they understand that the shortening of length is entirely due to shrinkage, such shrinkage depending, of course, upon the chemical composition of the metal. Is it not true that the coefficient of expansion and contraction of such type of metal is equal, regardless of size? What, if any, would be the difference

in length of the following two castings: 1 x 1 x 12 inches and 2 x 2 x 12 inches, of similar composition, if both were allowed to cool slowly in the sand? Theoretically, and according to the laws of physics, there should be no difference in length. If there is a difference it will be due to deformation caused by the surrounding, cooling metal. An example of this may be noticed in the arms of pulleys and other shapes of similar design where the metal is unequally cooled. Warpage in casting and other types of metal is due to unequal cooling.

Internal Ruptures

It is often quite noticeable in the failure of metal that internal rupture had occurred previous to failure. An indication of the above would be a dark and fairly smooth surface, located at the center of the bar or otherwise, where apparently such rupture or failure began. These conditions are probably due to a combination of causes and more than likely to inherent defects, caused by the segregation of nonmetallic impurities, gas pockets, etc.

If such defects existed they would quite naturally cause a discontinuity between adjacent metal, consequently reducing the tensile strength in proportion to the size and number of such spots or islands in the mass. Therefore, any tension or vibratory stresses applied would tend to, or may cause, a microscopic rupture adjacent to such islands of weakness, which rupture, in turn, may eventually start fatigue failure from many centers. The photographs of Fig. 6 and Fig. 6a indicate these points.

Figs. 5 to 8 illustrate some of the contributing causes for rupture due to resistance, etc. Fig. 7 represents a large section of metal, the surface of which is divided into imaginary layers, indicated by Nos. 1, 2, 3, 4, 5, etc. Let us, therefore, trace the possible effect of surface heating upon such large castings or billets of steel, i. e., reheating from a cold state to the various temperatures necessary for annealing, heat treating or forging.

Upon the application of heat to such a mass of metal the outside layers or strips, 1, 2, 3, etc., heat first and are usually heated from each end toward the center. Consequently, such heating will cause extension in length of the part so heated, and this extension in length continues without loss of strength up to a temperature of 650 degrees Fahr. (Fig. 1).

Knowing these facts to be true, have we seriously considered

the possible abnormal stresses that may be exerted upon the portion of the metal last heated and the effect such stresses might have upon those inherent defects? Is it not conceivable that such stresses may cause a slight microscopic rupture across an imagin-

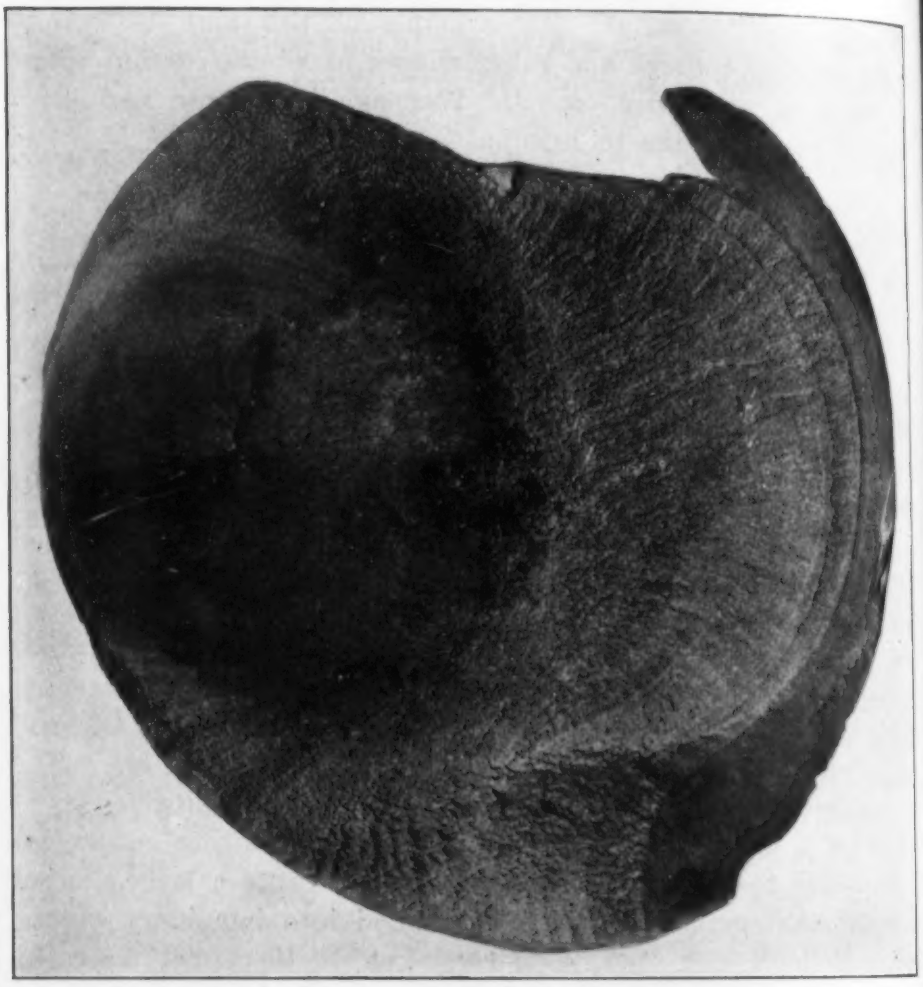


Fig. 6—Photograph of a Steel Bar which Failed Due to Fatigue. Failure Probably Due to Internal Rupture.

ary path of y-x-y, Fig. 7? This path would be the line of least resistance to concentrated stresses induced by the surface layer of metal extending longitudinally. The greatest danger in the heating of metals is in the preheating from atmospheric temperature to 650 degrees Fahr. for steel and 800 to 900 degrees Fahr. for cast iron. If it were possible from an industrial standpoint to handle large and small masses of metal that require further

heat treatment before they cooled to atmospheric temperature, much of this trouble would be reduced and probably eliminated.

From a metallurgical standpoint, it is not necessary to allow certain types of metal to cool to atmospheric temperature for the

Fig. 6a—Two Views of a 12-inch Bar which Failed Due to Fatigue.

purpose of again reheating for annealing, etc., unless it be for the convenience of handling. All that is necessary is to allow such parts to cool below the lowest point of the critical range. It would be interesting to know why metal industries do not utilize the heat energy contained in large masses of metal and thereby save fuel and time, with a possible reduction of internal stresses and probably rupture.

Internal rupture of a hardened steel block and dies may also be traced to the above rapid heating because such condition induces stresses upon the hard brittle center and may cause micro-

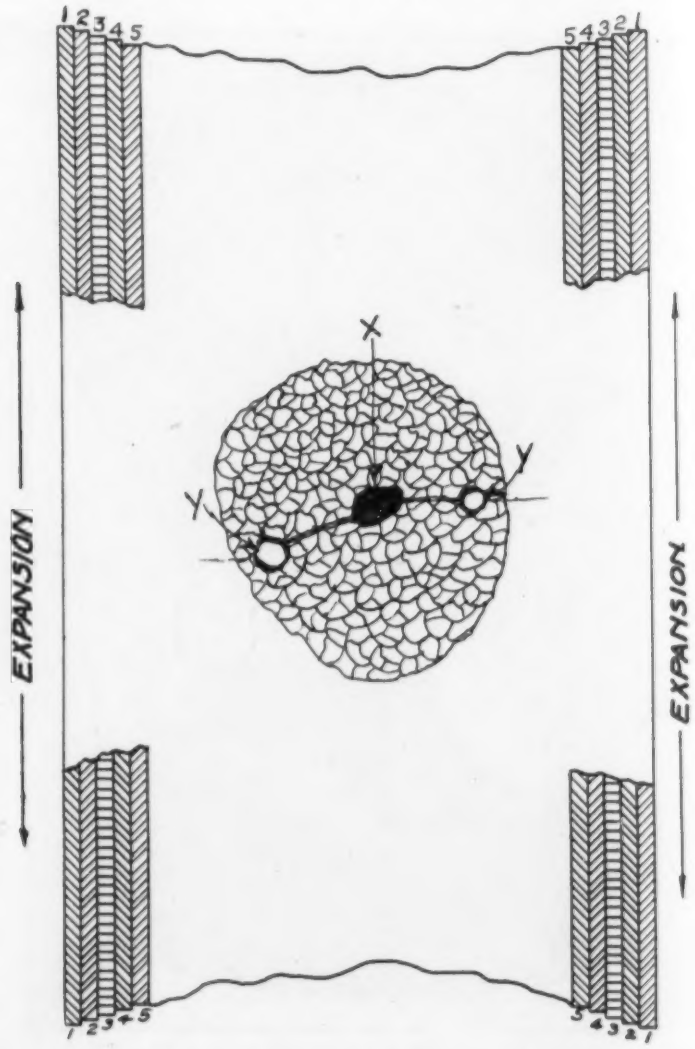


Fig. 7—Internal Rupture Due to Surface Expansion.

scopic rupture, and such rupture may not be noticeable after annealing, etc., but such a rupture may be the contributing cause of the bursting of the block when it is again rehardened.

Warpage Due to Localized Heating

To prevent deformation of metal due to localized heating, it is important that the metal be "*heated uniformly.*" Theoreti-

cally, the ideal heating would be to suspend the metal in a cylindrical furnace or support it in a horizontal position with sufficient space on all sides for the free circulation of heat. The sup-

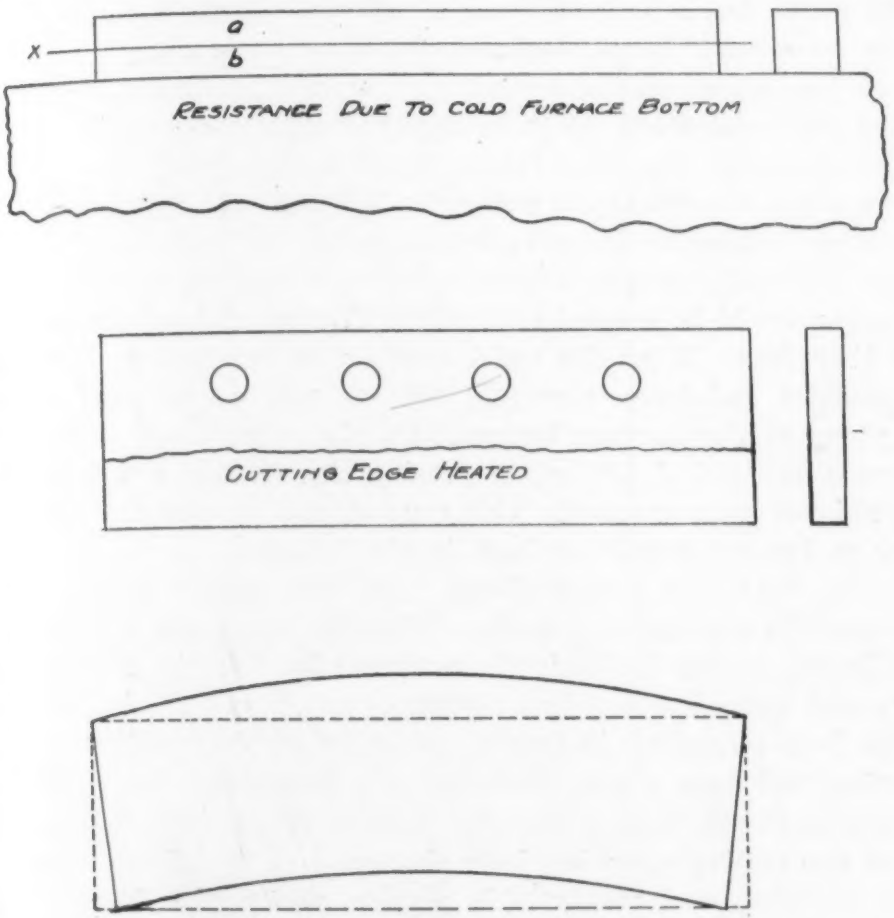


Fig. 8—Warpage Due to Local Heating.

ports would be for the purpose of preventing the metal from bending while it is in a weakened state, especially while it is passing through the transformation points. Therefore, to illustrate the effect of local heating, the three diagrams of Fig. 8 are presented. The upper figure represents a cold furnace bottom and (a.b) represents a piece of square stock to be heated.

It is sometimes a custom to load a cold furnace with finished metal parts to be heated and, after loading is completed, to light the burners. Quite naturally, the top bar (a) would heat first, consequently, that portion of the metal would expand and extend in length, causing the heated portion of bar (a) to hump up-

wards in the center. This hump would continue to increase until portion (a) of the metal had attained a temperature above 650 degrees Fahr. Upon further rise in temperature portion (a) of the metal would become weaker. At this point in the heating, the resistance of the cold portion (b) would cause a slight deformation (upsetting) in the weaker portion (a). With further upsetting the metal would quite naturally straighten out again. However, as the lower portion (b) increased in temperature there would be a slight reversal of the hump; in this case both ends would rise, causing further compressive action on the top and weaker metal (a). This action would continue until the stresses are equalized, and the bar would be warped out of line if removed from the furnace at that time. When the metal reaches the temperature of transformation (minimum strength) the bar may adjust itself to the contour of the furnace bottom. On the other hand, if the bar were a cylindrical section, in passing through the first hump, it would roll over or *crawl*. This type of heating will cause such a bar to become warped or bent in the furnace.

In the center figure of Fig. 8 is illustrated a problem that frequently appears in practice. This is a shear-blade 36 inches in length, having had only the cutting edge heated. In this case the cold metal has sufficient resistance to prevent the heated portion from extending in length, consequently deformation or upsetting will take place; therefore, the heated portion would be the same length when hot as that of the cold portion. This means that the cutting edge has been shortened 3/8 inch. On allowing the metal to cool slowly, this portion must either elongate 3/8 inch or bend the cold portion, as shown in the lower figure of Fig. 8, or, perhaps, cause rupture.

Shortening of Length by Repeated Heating and Cooling of Steel

We know from experiments that the repeated heating and cooling of steel will shorten its length, with a corresponding increase in diameter. There have been many scientific explanations presented as the cause for such condition, but the author believes that the following is the real contributing cause for the shortening of length. When steel is heated above its critical temperature the metal is in an expanded state. When quenched from this state, what portion of the metal will cool first? The

sketch in Fig. 9 represents a cylindrical section of steel which is divided into imaginary cooling rings numbered 1, 2, 3, 4 and 5. When this metal is plunged into water we could expect ring

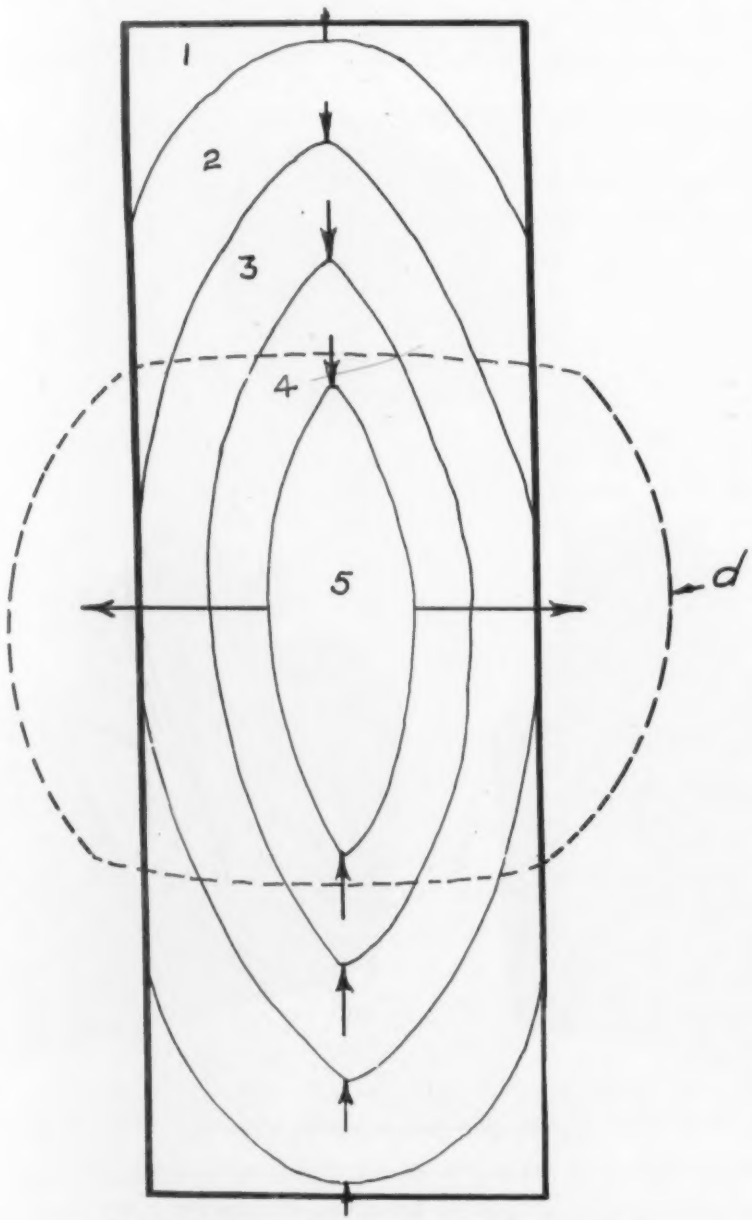


Fig. 9—Diagram Illustrating the Shortening of the Length of a Bar of Steel Due to Repeated Heating and Cooling.

No. 1 to cool first and the others in their order. These rings, in cooling, must shorten in length, consequently they exert a compressive action on the last portion of the metal to cool, the cen-

ter. As the side walls at this point are the areas of least resistance, the metal follows this path. If heated and quenched a sufficient number of times the metal would assume the form of a sphere, indicated at (d), Fig. 9.

This condition actually takes place in the repeated heating

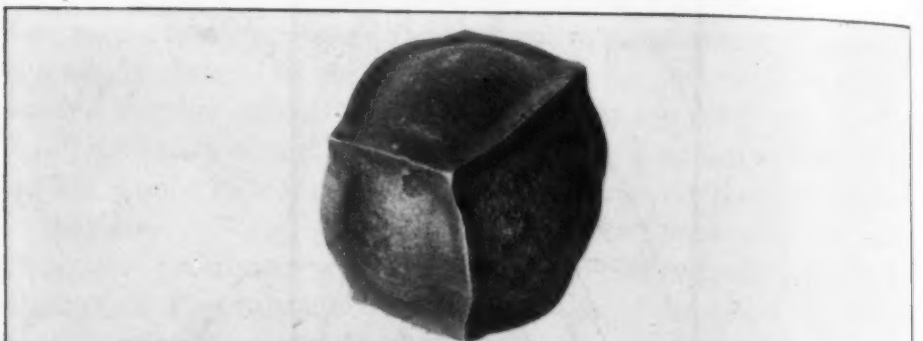


Fig. 10—Photographs of Pieces of Steel which have been Repeatedly Heated and Quenched.

and quenching of a block of steel, as shown in Fig. 10. A record[1] of repeated heating and quenching of a rectangular section indicated an average shortening of length of 0.004 inch per quench. At 350 quenchings, the steel became nearly a perfect sphere. A photograph of the original sample and the results are presented in

[1]The test specimens shown in Fig. 10 were prepared and heat treated by Eugene Stirnkorb of Fort Wayne, Indiana.

Fig. 10: original sample, at (a), results of quenched sample, at (b). Dimensional changes shown in Table I.

Other experiments along similar lines show that in each case where a rectangular section was used as a specimen, the weaker sides of the rectangle always bulged out in the center, a small sample of which is shown in Fig. 10, (c) and (d). These experi-

Table I

Dimensions of a Specimen of Low Carbon Steel After Heating and Quenching from Above the Upper Critical Point 350 Times

	Original Size	1	2	3	4	5	6	7	8	9
Length	2.500	2.497	2.492	2.489	2.486	2.484	2.480	2.475	2.470	2.467
Width	2.000	1.997	1.996	1.994	1.994	1.994	1.992	1.990	1.990	1.990
Thickness	1.312	1.319	1.325	1.333	1.339	1.350	1.357	1.368	1.373	1.378
Quenched	10	15	20	25	35	45	60	100	150	250
	2.465	2.447	2.420	2.400	2.372	2.348	2.318	2.357	2.315	2.258
	1.990	1.987	1.983	1.985	1.989	1.993	1.999	2.033	2.086	2.118
	1.382	1.439	1.482	1.511	1.612	1.662	1.754	1.920	2.037	2.120
Quenched	300	325	335	350						
	2.228	2.216	2.215	2.207						
	2.145	2.167	2.167	2.170						
	2.170	2.204	2.207	2.224						

ments clearly indicate the *deformation* of metal along the "path of least resistance." The specimen marked (e) was produced by Mr. Stirnkorb in repeatedly heating and quenching a block made of nonshrinkable steel. The reason for nonshrinkable steel block (e), Fig. 10, assuming a shape diametrically opposite to that of blocks (b) and (c), Fig. 10, would be interesting information to tool designers and heat treaters.

F. C. Lau of Chicago has successfully heated and quenched a piece of 1.15 per cent carbon steel ½ x ½ x 3½ inches 450 times without cracking. To accomplish this, careful preheating was necessary. The metal assumed an ellipse similar to a small football, except that a depression occurred on both ends of the long axis, similar to the depression of top of (c), Fig. 10.

Warpage Due to Unequal Cooling

Assuming that a piece of metal has been heated uniformly in order to prevent stresses or deformations, unequal cooling will cause warpage. Such warpage will occur in all types of castings, forged

or heat treated metal parts that are handled in this way. Such warpage is due to the compressive action of the portion so cooled, shortening the length of the uncooled portion. In other words, the length of the uncooled portion will be the same as the section cooled in water. In Fig. 11 we have a rectangular or other section of metal with one-half quenched, therefore, permanently set, the other half red hot, and both the same length. Is it not conceivable that when

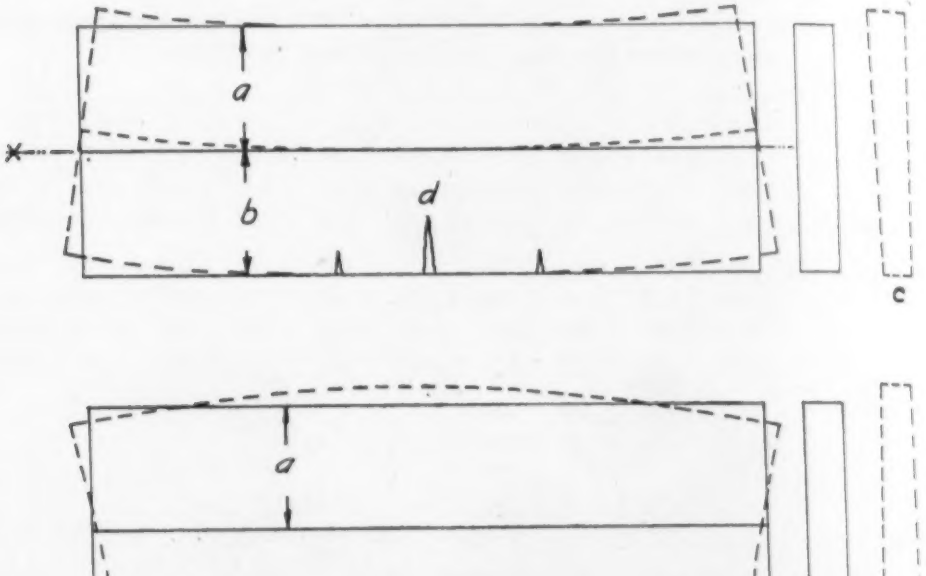


Fig. 11—Warpage Due to Unequal Cooling.

the heated portion shortens its length by normal contraction that some distortion or deformation must have taken place? In order to illustrate these points, the simple experiment shown in Fig. 11 is suggested.

In selecting the material for the first phase of this experiment a low carbon steel should be obtained (commercial stock) about ½ x 3 x 8 inches, perfectly straight, and its dimensions recorded.

The specimen should be heated uniformly to above its criti-

cal range, immersing the lower portion, marked (b), to the line marked x, holding in this position until the uncooled portion out of the water, marked (a), has cooled to a black heat, then re-quenched all over.

Checking the measurement, it will be found that the top edge of (a) has become shorter in length with a corresponding increase in cross-section indicated at (c). Conversely, the lower edge of (b) will increase in length in proportion to the amount that (a) has shortened in length, and likewise there will be a corresponding decrease in cross-section indicated at (c). The reason for the top portion of (a) shortening in length is obvious from past statements and experiments. However, it may be well to again emphasize the cause. When section (b) cooled quickly it shortened or contracted to its normal length at atmospheric temperature and it also developed maximum strength. In shortening its length it likewise shortened the length of the adjacent heated portion remaining out of the water. Therefore, when (a) cooled to atmospheric temperature it was shortened in length because section (b) had upset it, consequently, the entire section when cold would be similar to the heavy broken line, with the lower edge of (b) extended in length. This deformation or change of location of metal is a natural law in the bending or deflection of plastic materials from a straight line. This particular movement of metal is clearly illustrated when attempting to bend a similar section edgewise, the neutral axis of which would remain constant, the inside radius becoming shorter in length with increase in cross-section in proportion to the amount of deflection. Conversely, the outside radius decreases in cross-section with a corresponding increase in length. From the above statement it is clearly evident that the experiment of Fig. 11 has followed the same laws of deformation. If heated and cooled often enough one may form a small ring in this manner by repeatedly cooling the same portion. If after the first quenching the bar is reheated and quenching is duplicated on the opposite side, the metal should return to a straight line. Upon further measurement it will be found the bar would be shorter in length and in proportion to the amount of upsetting by the above two operations of quenching each side.

The next experiment suggested in Fig. 11 is an exact duplication as to procedure in treatment except that both edges or sections marked (a) and (a′) are to be cooled quickly. In this case

deformation must take place in the uncooled portion, the center, marked x. Warpage, of course, would be the natural result, as indicated by the heavy broken lines.

It may be well to pause here and seriously consider that a similar condition of *deformation* occurs under such treatment and that such deformation may be the contributing cause for the bursting or rupture of large and small masses of metal so cooled.

Warpage and Cracking in Tool Steel

In the above experiment (upper figure), Fig. 11, no rupture should take place, due to the ductility of the material. However, if we substitute tool steel or other hard brittle material for the above two experiments it will be noted that *deformation* will take place and to a greater extent, probably due to the quenched portion developing greater compressive strength in upsetting the uncooled portion, and also to the possibility of the quenched portion shortening its original length, as indicated in other experiments, and thereby acting on the uncooled portion likewise.

If we analyze the cause for cracking or rupture under the above conditions, we find a variable in strength; the section having the maximum (due to quenching) is hard, brittle and nonresilient, while the adjacent portion is weak and ductile, and in addition is endeavoring to shorten its length by normal contraction after deformation has taken place. The stresses induced thereby cause a bending action upon the hard rigid metal.

Under these conditions, if bending actually takes place, and it must, to some extent, under the above condition of adjustment to length, the hardened surface may develop a microscopic crack at the point of greatest stress or the point of greatest weakness. If the stresses continue to increase they will, undoubtedly, concentrate at the particularly weak points, therefore may cause one or more cracks to develop, as illustrated at (d) in the upper figure of Fig. 11.

If the hardened surface withstands such deflection stresses, failure may occur at the end of the bar and on the line of demarcation between the hard and soft metal. In this case the hardened section may be likened to a spring-board returning to its normal position after the load or stress is relieved. If failure does not occur at the end of the bar and a slight rupture occurs at the center point (Fig. 11), continued stresses may cause complete

rupture across the bar or to the line of demarcation and then follow that line of least resistance. An illustration of this point may be found in Beardsley's "Heat Treatment of Tool Steel," page 102.

If rupture does not occur under the above conditions the

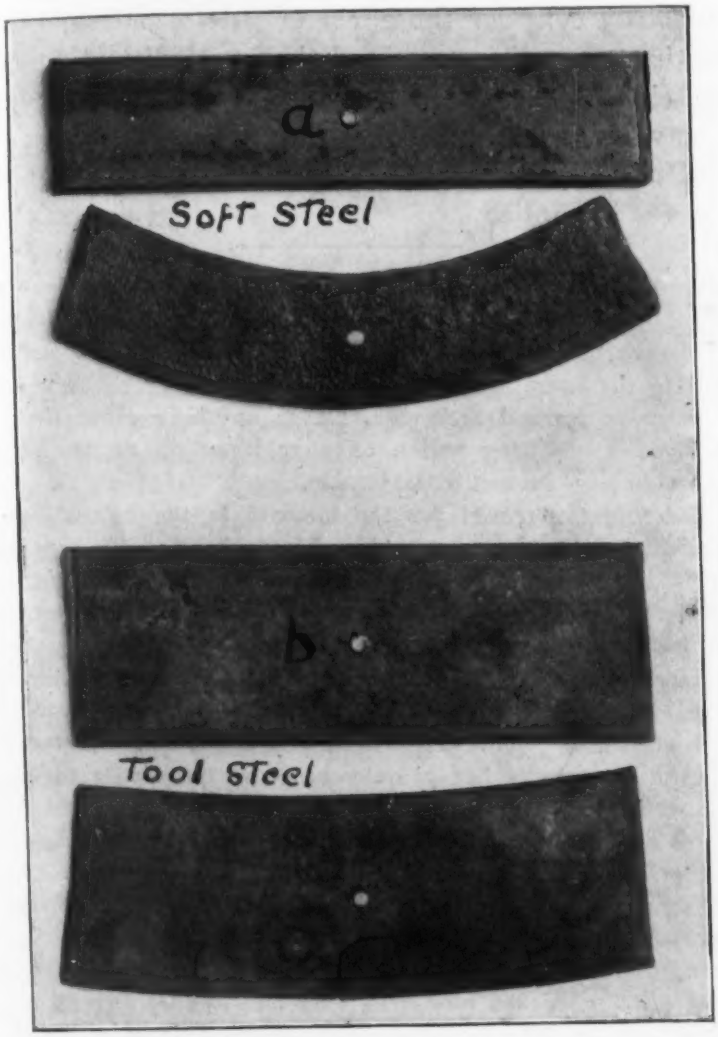


Fig. 12—Warpage and Cracking Due to Cooling Lower Half of a and b.

metal will be under excessive stress and may fail when least expected unless relieved by tempering or drawing. The low temperature at which hardened dies, etc., are drawn, only partially relieves such stresses. Complete removal of these stresses would occur only at a temperature known as low anneal. However,

tempering, drawing or annealing will not change the deformed metal to its normal dimensions it had previous to quenching. Therefore, the points to remember are to prevent, as much as possible, the deformation of metal by "heating and quenching uniformly."

If provision could be made to uniformly cool metal from the cast state, and if steel workers, welders, steel treaters, and others would seriously consider the effect of "deformation," due to unequal heating or cooling, much of the usual distortion (warpage) could be eliminated. This warpage creates stresses and these stresses may cause microscopic hairline cracks which, in turn, will undoubtedly cause complete rupture, especially when excessive load or stress is applied.

Written Discussion:—By S. A. Richardson, Interstate Iron and Steel Co., Chicago, Illinois.

It is the writer's opinion that Mr. Keller's paper constitutes a real contribution to the literature of practical heat treating. The writer believes that had he never learned from Mr. Keller anything other than how steel may warp by the upsetting action of a cold section on an adjoining hot section, he would have learned considerable.

In considering the reason for the increase in the deformation of tool steel as compared with mild steel in Fig. 11 of Mr. Keller's paper, the writer has found it interesting and profitable to take into consideration the influence of the volume changes of the metallographic constituents of heat treated steel. For instance, martensite—the constituent produced by quenching tool steel in water—has the largest volume of any of the constituents, so a piece of tool steel in the water quenched condition is larger—assuming proper heating and quenching—than in the annealed condition. This explains why many parts that fit exactly before quenching are frequently too large afterward. The writer recently saw a number of 30-inch shear blades made of S. A. E. 1095 steel, which after quenching were all $\frac{1}{16}$ inch too long.

The other constituents—troostite and sorbite—produced by a slower rate of cooling or by tempering a water quenched piece, have smaller volumes. So when troosto-sorbite occurs in quantity beside martensite in the same piece, warping or cracking must result. Careful tempering of the upper half of a piece of water quenched tool steel, long and slender enough to permit of some bending, will produce an appearance similar to that shown in Fig. 11, with the tempered half shorter. The writer considers this effect due to the smaller volume of troostite and sorbite. If a piece of 0.90 per cent carbon steel backed by a piece of 0.15 per cent carbon steel is heated and quenched, the composite piece will bend—the tool steel side becoming convex and the low carbon side concave. The writer considers this condition due to the increased volume of martensite, there being six times as much martensite in the 0.90 per cent carbon steel as in the 0.15 per cent carbon, if indeed the low carbon steel is martensitic at all.

The writer is inclined to consider, therefore, that in connection with Fig. 11 the warping of the low carbon steel is due essentially to upsetting as so clearly shown by Mr. Keller, and that the much greater warping of tool steel is due, in addition to the upsetting that undoubtedly occurs in about the same amount as in mild steel, to the difference in volume of the several metallographic constituents occurring in the piece due to the variation in the rate of cooling. On this basis, with suitable conditions, uneven tempering would be almost as likely to produce distortion, though perhaps to a lesser degree quantitatively, as uneven quenching.

Mr. Keller's suggestion on the fourteenth page of his paper, concerning the possible over-emphasis of shrinkage as the cause of defective castings is interesting. Unquestionably, every foundryman could profit from a study of this suggestion, although some of the reasons for blaming shrinkage for the trouble seem well established. A foundryman would point out, for instance, that the breaking of castings can be minimized in many cases by the proper location of risers, feeders, etc., which tend to offset or take up the shrinkage. Likewise, a steel casting poured at 2750 degrees Fahr., for example, would in general be much less likely to crack than if poured at 2900 degrees Fahr. —there being a fairly definite relation between pouring temperature and shrinkage. In iron founding, a casting of given design that could be cast successfully in grey iron, might crack in every case if cast in white iron, due to the greater shrinkage of the latter.

It would appear, then, that most of the foundryman's difficulties have their origin in or close to the solidification zone, rather than in the heat treating range, although a careful study should show many cases, no doubt, where Mr. Keller's suggestion would prove a valuable aid in the solution of cooling troubles.

Oral Discussion

A. H. FRAUENTHAL: I would like to ask if there is any relationship between the quantity of deformation and the direction of fiber in steel?

PROF. J. F. KELLER: The subject matter presented in this paper has not been studied from a laboratory or metallographic standpoint, therefore I am unable to answer your question. I am inclined to believe, however, that the direction of fiber in steel, if any, would have no appreciable effect in resisting deformation under the condition described. Our original intention in collecting the thoughts presented were for the purpose of preparing a bulletin on the subject for the benefit of the metal industries of the State of Indiana and as a large percentage of the workmen are non-technical we decided to avoid discussing technical phases of the subject which might create confusion in their minds. Personally, I wanted to get the simple thought across to these men that when metal is heated or cooled unequally, "deformation" usually takes place.

Just how much "deformation" has taken place I have not had time or facility to measure. However, I am satisfied in my own mind from many years of experience and experimentation on the points presented in this paper, that such "deformation" does occur under the condition described. To those

who are skeptical as to such occurrence I would suggest they try out some of these experiments, to either prove or disprove them.

The object in presenting this paper to the Society was for the purpose of arousing interest among men having problems of this character and in particular to interest scientific men having time and facility for scientific investigation along the line above suggested. If either one of these points is accomplished I will feel well repaid for starting an argument that may remove many of our present day problems on the subject.

MR. CREON: I would like to ask in regard to that one rectangular piece which seemed to fracture from having been improperly quenched (referring to (b) Fig. 12). Had that been immersed entirely, would not that have prevented that cracking from the bottom?

PROF. J. F. KELLER: Yes. That is the point we are trying to bring out in this paper—uniformity of heating and quenching. On the contrary, if there is a nonuniformity of heating, cooling or quenching a "deformation" will take place in the portion last cooled and it is such "deformation" that we believe is the contributing cause for abnormal stresses both in the quenched and un-cooled portion. We also believe that it is such stresses that cause cracking on the hardened non-resilient quenched side.

ARTHUR HUNGELMANN: I should like to ask Professor Keller if he has any data on the relative effect of different elements on this phenomena he has described.

PROF. J. F. KELLER: No, I have not. The experiments suggested in the paper have been performed with iron, soft steel and carbon tool steel. However, we find that alloy steels will also distort perhaps not to such a great extent but we have no definite information on this phase of the subject; therefore, I do hope some research department of our engineering schools or some interested metallurgical engineer connected with a large industrial concern may find time to develop some authentic information on this interesting subject.

GUSTAV PIRK: Mr. Harrison of the General Electric Research Laboratory has found a similar effect in pure iron. He used an iron wire 10 mills in diameter and made it into a hairpin and put that in hydrogen. After reheating some five or six hundred times, he found that he could shorten the wire about 13 per cent of its original length. He tried the effect of silicon and he found that the surface of the wire when it shortened became exceedingly rough. He is making further experiments and he intends to publish this work. He did not set out with the idea of proving anything about contraction of metals on repeated heatings and coolings. It was in an attempt to find some metal which would clean up hydrogen, by removing the oxygen and clean up other obnoxious gases, that he found this effect.

C. T. PATTERSON: Straight carbon tool steels and piano wire such as you used have only one critical point hence the volume change takes place all at one time and temperature.

Alloy steels of the non-deforming die type in particular have several expansion and contraction points, due to the alloys, hence, the volume change is not nearly so great at any one time and temperature and often occurs over a wide range of temperature. This makes it possible to produce a heat treated block which is practically the same size as it was before treatment.

DILATOMETRIC METHOD OF HEAT TREATMENT

By O. E. Harder, R. L. Dowdell, and A. C. Forsyth

Abstract

In the present paper the writers are reporting the progress in the use of the dilatometric method of heat treatment and the application of that method to the study of dimensional changes in such materials as gray cast iron. Two slightly different pieces of apparatus have been constructed and used. The details of construction and the results obtained are given.

Introduction

TWO investigations which have been in progress in the department of metallography, school of mines, University of Minnesota, viz., the dimensional changes during heat treating steels and a similar study of gray cast iron, have led to the development of two pieces of apparatus which seem to be of sufficient importance to justify reporting their construction and operation. The first apparatus may be called a dilatometric heat treating furnace and the second simply a dilatometer.

Theory of Dilatometric Heat Treating

The phenomena of the volume changes which take place on heating or cooling a steel through its critical points have been known for a long time. For example, if a eutectoid steel is heated it will expand uniformly so long as it is below its critical point; however, when the eutectoid temperature is reached there will be observed a break in the temperature-volume curve. The volume of the steel will remain constant or even contract until the cementite is in solution with the ferrite, after which it will continue to expand at a uniform rate as the temperature is raised. On cooling, just the reverse changes will take place; that is, the steel will contract until the eutectoid temperature is reached ($Ar_{3.2.1}$), then remain constant or even expand until all of the cementite has been

A paper presented before the Cleveland Convention of the Society, September, 1925. Of the authors, O. E. Harder is professor of metallography and R. L. Dowdell is instructor in metallography, School of Mines, University of Minnesota, Minneapolis, Minn. A. C. Forsyth received the degree of Metallurgical Engineer at the University of Minnesota, and is at present in the foundry department of the Bethlehem Steel Co., Bethlehem, Pa.

precipitated from the austenite solid solution, after which it will continue to contract as the temperature is lowered. At the discontinuities in the dimensional changes the temperatures will also remain quite constant.

A commercial hardening apparatus[1] for the heat treatment of tools, dies, etc., is now on the market operating on this principle

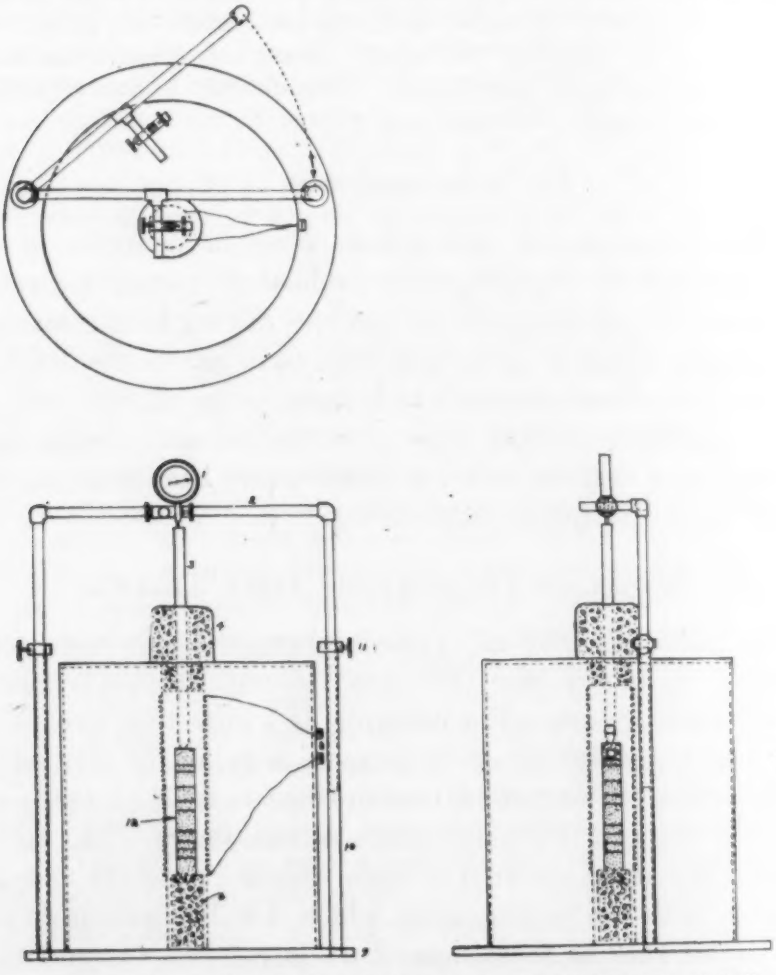


Fig. 1—General Set-Up of Furnace for the Dilatometric Method of Heat Treating. The Three Views show the Top, Front and Side.

of constant temperature during the passing of the steel through the critical range. This apparatus records the temperature arrests in the steel being treated, by means of a thermocouple within the mass of steel parts. In the hardening of tools and parts having a narrow critical range, this method has many advantages which

[1]G. W. Tall, Jr., "The Hump Method of Heat Treatment," TRANSACTIONS, American Society for Steel Treating, January, 1920.

result in a greater uniformity of hardened parts than is possible by the usual furnace methods where the pyrometer is placed away from the steel being treated. The writers have constructed and used a furnace operating on the dilatometric principle and obtained some very encouraging results.

Construction of Furnace

Fig. 1 shows the general set-up of a furnace for the dilatometric method of heat treating in three views: top, front, and side. The experimental furnace is of the electrically heated type with a heating element consisting of about 53 feet of 16 gage nickel-chromium wire. The electric furnace installation is probably more efficient on this type of work, although other methods of heating, doubtless, can be used. With the electrical method it is easier to design the furnace so that the distribution of heat in the furnace chamber will be more even and insure a greater uniformity of heating of the steel.

The details of the furnace construction are as follows: At the lower end or bottom of the heating chamber is a common firebrick base (6), Fig. 1, which rests directly on a mild steel base plate (9). The steel to be hardened (12) is piled up on this firebrick base. A fireclay furnace lid (4) also serves as a guide for the push rod (3), which is made of invar steel, fused silica, or any material with a low coefficient of expansion. This push rod operates the movable plunger of an indicator, such as an Ames dial (1), which measures the expansion to one-thousandths of an inch. This indicator is clamped to the pipe framework (2), which, in turn, is secured to the pipe stanchions (10) by the clamps (11).

Operation of Hardening Furnace

After the steel is placed on the firebrick hearth, the lid is put on and the push rod is adjusted so that it rests on the pile of steel; the frame work (2) holding the expansion indicator is swung into place, Fig. 1, and lowered into the stanchions (10) until the movable plunger of the dial rests on the push rod. The two set screws (11) are then tightened and the apparatus is then ready for operation. The push rod guide can have a relatively loose fit around the push rod without interfering materially with the readings of the indicator.

The heat input of the furnace can be regulated by any suitable transformer having a sufficient number of regulating taps, so that the most desirable rate of heating can be obtained for the different kinds of steel parts being treated.

Only a limited number of dilatation curves have been made with this apparatus. All the curves made to date are plotted in Fig. 2. Curves Nos. 1, 2, and 3 were obtained on a single piece

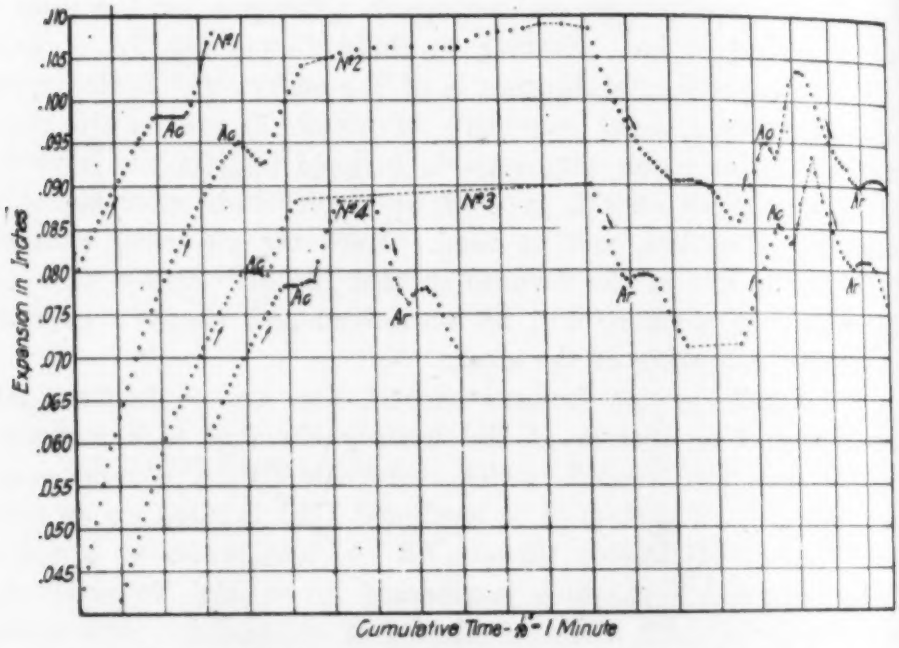


Fig. 2—Dilatation Curves Obtained on Apparatus Shown in Fig. 1.

of eutectoid steel ¾ inch in diameter x 6 inches long, with a rate of heating between 18 and 23 degrees Fahr. per minute from room temperature to the Ac point.

Curve No. 2, Fig. 2, on its first heating shows a decrease in length in going through the Ac. It will be noted that, after holding for one hour above the critical and cooling, the length remains quite constant during the Ar transformation, but on reheating a considerable contraction occurs at the Ac point, while on recooling the steel actually expands during the Ar transformation. The cause of the dimensions remaining constant in some cases and expanding or contracting in others during a transformation is probably related to the microstructure of the steel and to the length of time held at the temperature above the critical. However, this relation has not been studied.

Curve No. 4, Fig. 2, was obtained by taking seven discs of ¾-inch round eutectoid steel which, after stacking, made a pile of 6 inches overall in height. It will be noted that the seven loose pieces make almost as good a curve as one piece, showing that this method of heat treating is entirely practicable.

The critical points shown in Fig. 2 occur at different dilatometer readings because of changes in the zero setting of the dial and the fact that the curves were started at different temperatures.

It should be remembered that the calibration of the expansion indicator is of no importance whatever in determining the hardening temperature. The main point to be observed in hardening is to note the critical range by the sudden changes in the dilatometer readings. After this change is reached the tool hardener should heat to five or ten divisions (0.005-0.010 inches) on the dial above the critical (for a pile of steel about 6 inches high) and quench. However, in practice the speed of heating and the type of steel being treated would determine the best dilatometer reading before quenching. This indicating dial pyrometer is equally, if not more, "fool proof" than the thermocouple.

Design of Commercial Furnace

A furnace designed to heat treat a pile of steel about 24 inches high could be well operated by this dilatometer. The dilatation would be just four times greater than when heating a 6-inch pile, but the relation and magnitude of the arrest in passing through the critical to the changes in the steel would be practically the same as shown for the six-inch piece (Fig. 2).

A more practical method of holding the dial would be one single rigid stanchion with a heavy hinged arm at right angles to it. This would facilitate faster and more efficient operation in charging, dial setting, and discharging. It would also be desirable to have an automatic expansion-time recorder which could be simply constructed so as to be autographic. The autographic feature would, of course, be desirable for checking the steel treater.

Construction of an Accurate Dilatometer

In connection with some investigations of cast iron a simply constructed dilatometer which may be of interest to metallurgists

was made up to measure the growth which takes place in gray iron during cycles of heating and cooling from elevated temperatures. What has been found to be an accurate dilatometer for high temperature work is not a complicated piece of apparatus, but is simple and can be constructed at a low cost.

Fig. 3 shows three views of a dilatometer built along lines somewhat similar to the one used by Andrews, et al.[2] Part No. 3

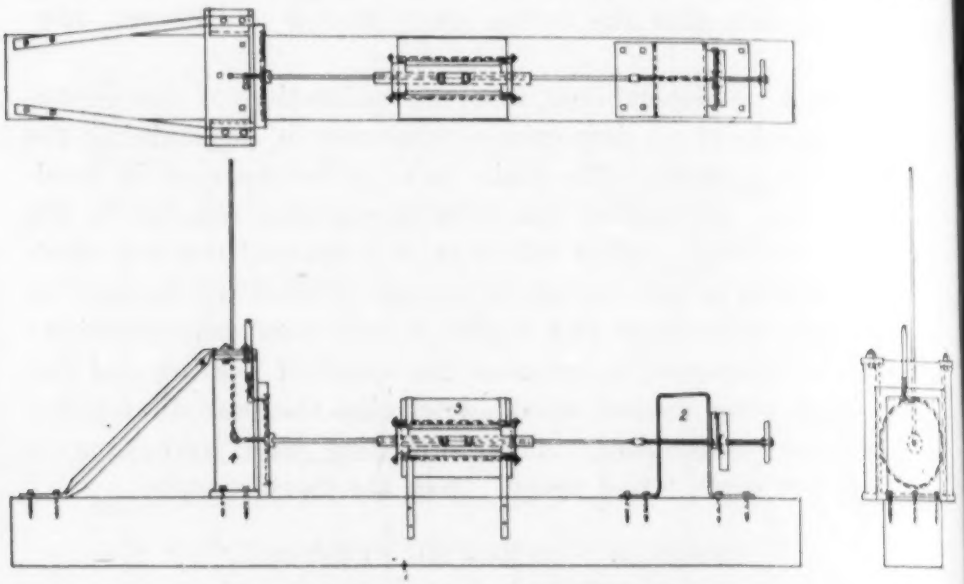


Fig. 3—Direct Reading Dilatometer.

is an electric tube furnace used for heating specimens 2 inches long x ¾ inches in diameter with a ¼-inch hole in the center for the hot junction of a thermocouple and also to better enable all parts of the specimen to come to the same temperature. The specimen slides within a silica tube with a comparatively loose fit. This tube is provided with an inlet and outlet so that any type of gaseous atmosphere can be applied. Two copper discs with holes about ⅛ inch deep make end contacts with the ends of the specimen and keep the silica push rod aligned with a center line through the tube. It would be much more desirable to have these discs made of silica on account of its low coefficient of expansion, but their construction of silica offers difficulties.

One of the push rods (18 inches long x ½ inches diameter) works against part (4), shown in Fig. 3. Fig. 4, however, shows a more detailed drawing of this diaphragm. Part (a) is a piece

[2]Andrews, Rippon, Miller and Wragg, "The Effect of Initial Temperature on the Physical Properties of Steel," *Journal*, Iron and Steel Institute, Vol. 101, p. 527-612 (1920).

of boiler plate 1 inch thick with a depression of 9 inches in diameter x 3/8 inch deep, machined out on one side of the plate. This depression forms the mercury reservoir. A small shoulder 1/8 inch deep with a $\frac{3}{16}$-inch base was machined around the outside of this depression. Part (b) is a circular steel disc which is fastened to part (a) by stove bolts. This connection is made tight by the aid of a rubber gasket in order to prevent a leakage of mercury. Parts (f) and (g) are of 1/4-inch pipe, which were

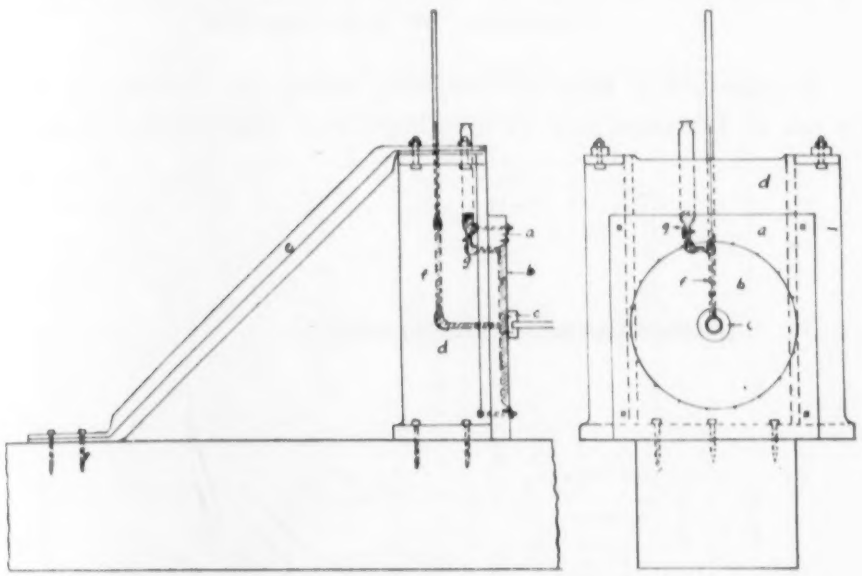


Fig. 4—Detailed View of Diaphragm as Shown in Fig. 3.

tapped through the plate to the mercury reservoir. A separatory funnel was cemented with sealing wax to part (g) and serves to regulate the amount of mercury in the reservoir. A capillary glass tube of $^1/_{20}$-inch bore was sealed into part (f), to be used as an indicator. The mercury level is controlled by the stopcock in part (g) and is so regulated that it does not flow into the capillary tube (f) when pressure is exerted on the disc. Since mercury is extremely sluggish when used in a $^1/_{20}$-inch capillary tube, blue ink was put in the tube on top of the mercury. If the slightest pressure was applied to the disc the blue ink meniscus would immediately respond by rising in the tube. Parts (d) and (e) are gray iron castings, which only serve the purpose of making the diaphragm rigid.

The other silica push rod makes contact with the specimen and the micrometer arrangement or regulating dial shown by

part (2), Fig. 3. This regulating arrangement is shown in more detail in Fig. 5. The regulating screw was made by threading a ¼ inch pipe with a common pipe die, which produced 18.25 threads per inch. Part (c) is a circular wooden dial 6 inches in diameter, which is divided around its periphery into tenths and hundredths. Part (b) is a wooden vernier (nine divisions of the 6 inch dial divided into 10 equal parts), made to slide only in a horizontal position.

Operation of Dilatometer

In operating this dilatometer, either on heating or cooling, the ink in the capillary tube is kept at a constant height by regu-

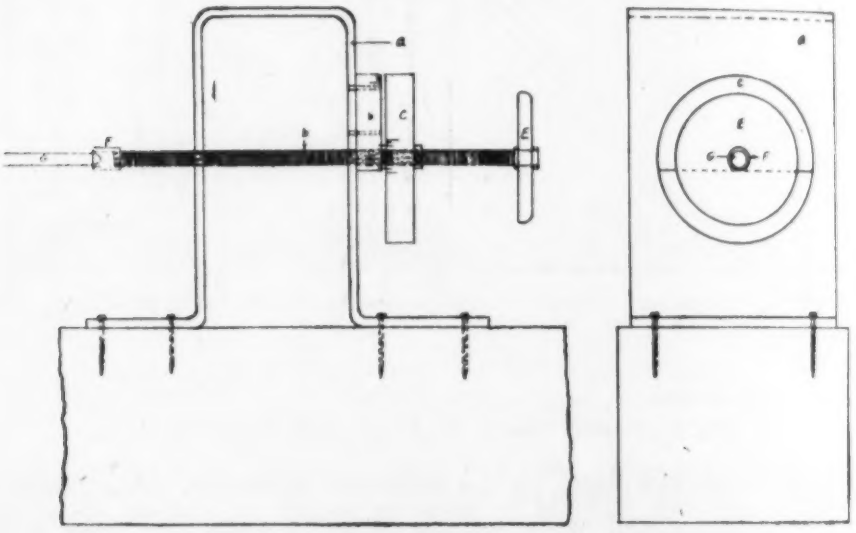


Fig 5—Detailed View of Dial Support as Shown in Fig. 3.

lating the hand wheel (E), Fig. 5, so as to keep the pressure on the disc constant. The reading of the dilatation or contraction is then made directly on the dial and vernier attached to the screw. The method used for reading the height of the ink in the capillary tube was to sight at the meniscus through a telescope fixed in position.

One complete revolution of the dial, or the advancement of one thread on the screw, is equal to 0.0547 inch. With the tenth, hundredth, and thousandth (vernier) divisions on the instrument it is possible to read to 0.0000547 inch. The accuracy of the reading, however, depends on the accuracy of the threads cut on the

regulating screw. If extreme accuracy is required, it is recommended that these threads be cut on a lathe with a larger number per inch. The dimensional changes of the parts making up the dilatometer will also have to be corrected, if extreme accuracy is required. These volume changes in the apparatus can be kept low by insulating the parts subjected to elevated temperatures and at the same time protecting those parts which it is desired to keep at constant temperature.

A dilatometer of this type can be used to determine the

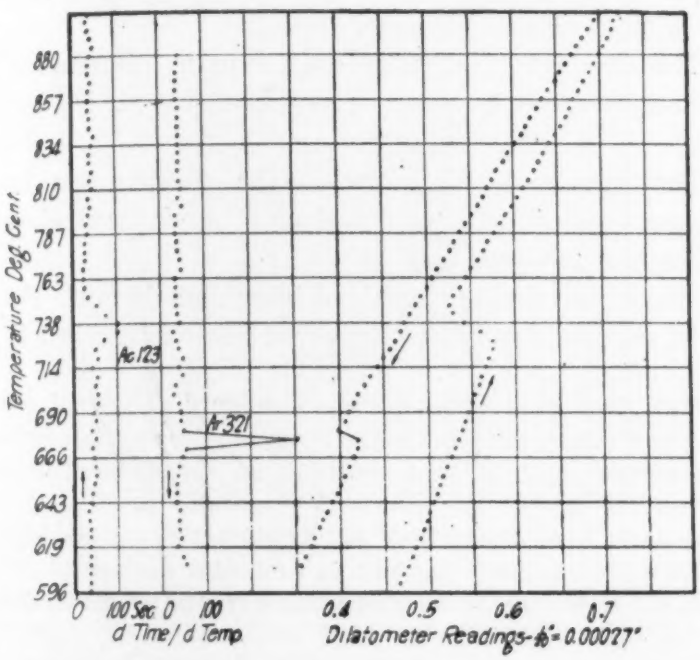


Fig. 6—Characteristic Dilatation Curve on a Specimen of Eutectoid Steel.

coefficients of expansion of various materials as well as for the determination of critical points. Fig. 6 shows a characteristic dilatation curve on a specimen of eutectoid steel plotted directly from the reading without correcting for dimensional changes of the instrument. The inverse-rate curve was made at the same time as the dilatation curve. It will be observed that the critical points are as well shown by the dilatation curve as by the inverse-rate curve. This apparatus has been found to be useful in studying the dimensional changes in gray cast iron during cycles of heating and cooling.

Conclusions

1. There is reason to believe that tools and dies can be as successfully hardened by the dilatometric method described above and with as much or more accuracy, as to the final size, than by previous methods, because the size of the part is being measured at all times during heating.

2. The application of this method of hardening would be best made in heat treating plants where equal numbers of the same part would constitute the heats.

3. An inexperienced heat treater could operate two or three furnaces with comparative ease.

4. The first cost and maintenance of a dilatometer pyrometer (non-recording) is much less than for the thermocouple pyrometer.

5. The results obtained with the dilatometer herein described have been satisfactory and such equipment should be of service in other laboratories.

6. The construction of this dilatometer is such that it can be made in the laboratory and the cost of construction is small.

Written Discussion:—By R. W. Woodward, Hartford, Conn.

The paper which the authors have presented gives an interesting account of some experiments made of heat treatment by the dilatometric method and intimates that the method has commercial possibilities. The object of the present discussion is to remove any doubt which the authors imply, and to show that the method not only has been in successful commercial operation for several years but is destined to take a leading place in refined methods of heat treatment.

Some ten years or more ago Stanley P. Rockwell became interested in the possibilities of the dilatometric method of heat treatment and during this period has made a detailed study of it with the final result of a practical apparatus for the commercial heat treatment of either tools or production parts.

Fig. 1 shows a view of this dilatometric outfit attached to an electric pit type furnace, although it may be connected to other suitable types of furnaces. The equipment as shown is arranged with an indicating dial to show the expansion of the steel, progress throughout the critical transformation range, and also an autographic attachment which produces a continuous record of the length changes.

Fig. 2 shows a record as produced in the hardening of a carbon steel milling cutter. Point A on the chart indicates the dimensional size at the time the work was placed in the previously heated furnace but with the heat supply shut off, and the dilatometer brought in contact. The work expands

at a decreasing rate to the point B corresponding to the amount of residual heat in the furnace. In other words, at the point B a temperature equilibrium between work and furnace exists, and all parts of the work are equally expanded. At B the fuel supply to the furnace is again applied so as to bring up the temperature of the work and the furnace at the same rate. Expansion of the work is again resumed and decreases slightly before the point C, at

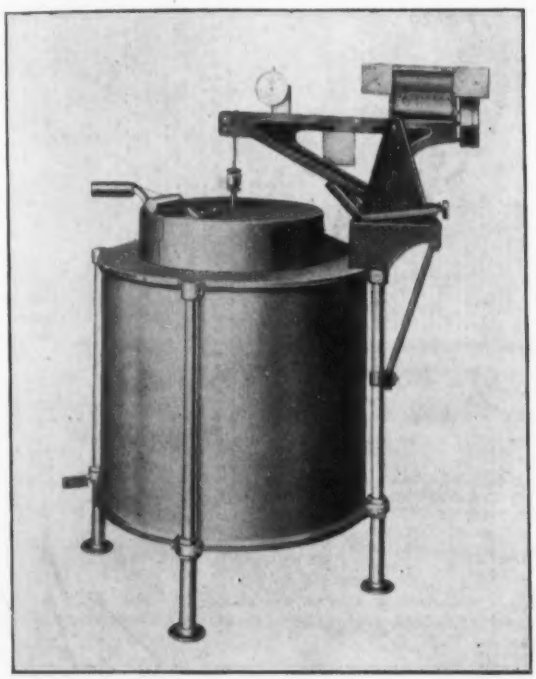


Fig. 1—Dilatometric Equipment Attached to an Electric Pit-Type Furnace.

which point there is a reversal in the direction of the curve. This reversal marks a contraction in the work, and is an exact indication that the steel is entering the critical transformation range. This contraction continues until the transformaion is completed at D on the curve. At the completion point D re-expansion then takes place, at which time the work is removed from the furnace for quenching. As a convenience to the operator an alarm attachment is provided so that a bell rings when point C is reached and continues to ring until point D is reached. It is also possible through suitable relays to arrange so that an additional signal is given when the point D is reached and the hardener is forcibly reminded that it is time to quench the article.

The chart of Fig. 3 represents a production record of the heat treatment of chromium-vanadium gear blanks.

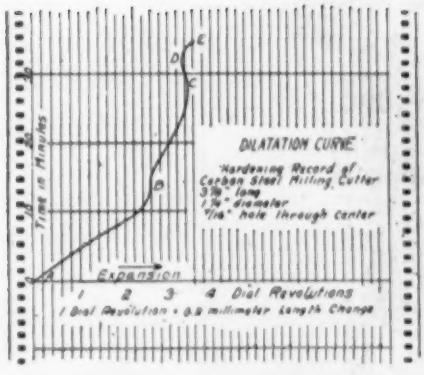
It might be well to enumerate some of the advantages which the dilatometric method of hardening possesses over other methods of heat treatment.

In the first place, the steel being treated tells its story, so as to speak, and by its own indication shows when the transformation point has been entirely passed as evidenced by re-expansion and that a quench will then

produce the absolute minimum of distortion, freedom from internal stresses and fine grain.

The rate of heating can be accurately guided using the expansion as a basis.

The dilatometric method is entirely mechanical and does not depend upon electrical or other indirect methods of measurement. If desired, how-



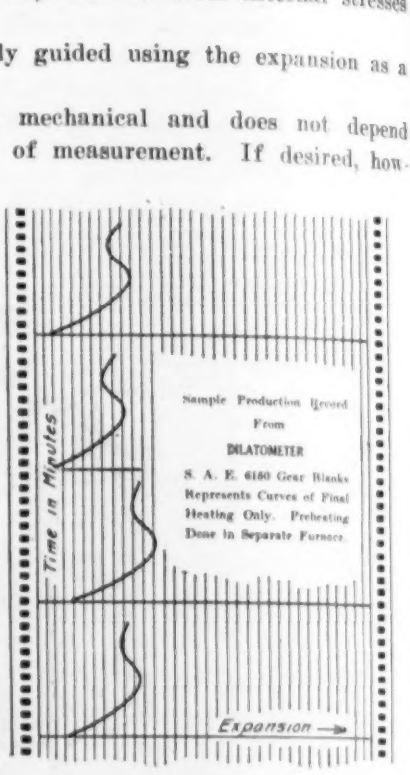


Fig. 2—Characteristic Dilatation Curve Obtained by the Equipment Shown in Fig. 1.
Fig. 3—Production Record Obtained from Heat Treating Chromium-Vanadium Gear Blanks in the Dilatation Equipment of Fig. 1.

ever, a pyrometer may be used in order to establish standards for other parts of like nature, and for this purpose the quartz tube may also be used as a thermocouple protection tube.

As contrasted with the time temperature method of critical temperature observance, there is no lag in the observation of the critical phenomena.

Fig. 4 shows a diagramatic view of a furnace with dilatometer and pyrometer attached. The dilatometer is in contact with the die to be hardened at D and the thermocouple hot junction in proximity at point C. Both the die and the hot junction of the couple receive heat from the furnace walls by radiation and convection. It is easy to see that the hot junction will receive a greater part of its heat energy from the hotter furnace walls and only a small part from the die. For this reason and others which are well known, the steel lags behind the temperature indicated. By the time that the dilatometer shows complete progress through the transformation the thermocouple has passed it, due to predominance of heat absorbed from the furnace. It is for this reason that by the time temperature method of heat treatment it is necessary to quench at an indefinite temperature beyond the observed critical temperature. With the dilatometric method this unknown factor disappears and the quenching may take place as soon as the re-expansion sets in.

In order to more clearly demonstrate this, a bar of tool steel 5 inches

long and 1 inch in diameter was heated in this equipment. During the period of heating, which was 1 hour and 35 minutes, temperature measurements were noted by a very delicate thermocouple and millivoltmeter. The thermocouple junction was in contact with the outside of the bar half way its length. Fig. 5 is the dilatometric chart.

If one considered temperature merely as an indication of decalescence,

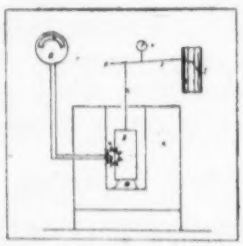


Fig. 4—Diagrammatic Sketch of the Dilatometric Equipment Described.

1380 degrees Fahr. would be the figure. Actually, contraction, which indicates true decalescence, begins at an indicated temperature of 1365 degrees Fahr. The meaning of this is that the heat emanation of the steel under treatment is too feeble to affect the thermocouple. This is the lag spoken

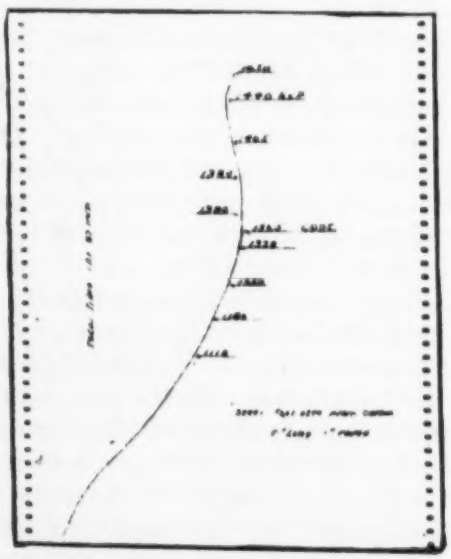


Fig. 5—Dilatation Curve of a Plain Carbon Tool Steel.

of. During the 1380 degrees Fahr. period constant temperature is maintained at the thermocouple junction. After the 1380 degrees Fahr. period the thermocouple temperature increases; contraction, however, is still strong. Again temperature error is apparent. At the thermocouple temperature 1440 degrees Fahr. re-expansion takes place, and full hardness is secured on quenching. The period on the curve noted by temperature masurement 1380 degrees Fahr. to 1440 degrees Fahr. represents the customary temperature

increase allowance found necessary when hardening by the time temperature measurement devices.

With the positiveness of this principle and the power which is evolved in the volumetric changes, electrical contacts indicating the changes are readily operated. These in turn may be made to operate electric motors for conveying, etc. An equipment has been designed to transmit transmission gear shafts from a preheating furnace, to the final heating furnace, thence to a quenching bath and finally to a tempering bath.

For a number of years airplane shaft tubing and similar work has been heat treated by the dilatometric principle. This is also used in large brass plants for annealing of condenser tubes.

Oral Discussion

J. W. HARSCH: In discussing the paper of Messrs. Harder, Dowdell and Forsyth, I wish to confine my remarks to that section which describes the dilatometric method of heat treatment.

The method as proposed by the authors of this paper offers interesting possibilities. The dilatometric principle has been and is now being used for limited types of work, such as the treatment of bar and tube stock, and it seems entirely possible that with the design of suitable apparatus the method might be applied to certain other types of work. The extent to which it may be applied will necessarily be determined by its degree of success under actual working conditions. Its most likely application being, as Professor Harder mentions, on uniform types of work.

Its commercial application to other types of work would, in the opinion of the speaker, involve a somewhat more intimate study of the effect of such variables as type steel and size and shape of work upon the control of rate of heating and of the final quenching point as determined by this method. It is, therefore, hoped that the authors may find it possible to continue their researches in this direction.

O. Z. KLOPSCH: Some two or three years ago the Bureau of Standards did a little work on some similar investigations, using both silica and quartz tubes. It was our experience that the ends of these rods would fuse onto the specimens. I wonder whether Dr. Harder has had the same experience?

Our results were the same as those of Mr. Woodward in that we also found contraction at the transformations on heating all steels that we tried. I would like to ask if Dr. Harder in his work on cast iron has ever tried anything but the longitudinal dimensions? We attempted to get two dimensions in our dimensional change work, because we felt that there would be two changes, both longitudinal and transverse. Mr. Woodward made the statement that if a steel sample were heated above the transformation point you would get full hardness. I think that the type of steel, its size and shape, and the medium into which it is quenched, are very essential points to be covered in stating whether the steel will completely harden or not.

CHAIRMAN STOUGHTON: Will you answer that now, Professor Harder, or wait until all the questions are in?

DR. O. E. HARDER: As you like. In regard to determining two dimensions, we have determined only one, and that has been the long dimension of the specimen. I am of the opinion that expansion is in all directions, depending, of course, upon cross section, relative cross sections and such other factors. We have measured only one, however. We have not had trouble with the action of the oxide or scale on the iron on the silica tubes, so far as we have observed. Of course, if high temperatures and an oxidizing atmosphere are used, I think we may get such a reaction between the iron oxide and the silica tube. Our curves show that we have in certain cases observed slight contraction and in other cases about a constant dimension. I think that again may depend upon the previous history of the steel and the type of steel used.

S. P. ROCKWELL: With regard to the sticking of the silica tube, I believe that it has been found that such things happen in pyrometry where a silica tube or quartz tube is used as the protection tube. I see no reason why it should happen in this case; in fact, we have tried this with using some of the special heat resisting alloys which have little thermal reaction themselves. Even very low carbon steel has been used where the critical temperature of the steel is higher than the critical temperature of the work which is being treated. It is simply that the expansion of that tube, or contact rod detracts slightly from the amount of the contraction that we would get by the dilatometric curve.

With regard to the various sizes of work, I see no reason why this method should be limited to uniform objects; in fact we have treated tools varying greatly, showing a ratio of ten to one on size and cross section of specimens. It simply devolves down into a question of the rate of heating.

As regards the full hardness, I have found on alloy steels, particularly on steels containing manganese, 1.10 per cent; say carbon 0.90 per cent, that full hardness is secured just after the turn, or just as soon as you get a definite turn. That applies also, we have found, to straight carbon steels. I think perhaps the only case where there might be some question of that is where steels are bought in a spheroidized condition and the final production desired is a condition where the spheroidizing is completely removed.

I might refer you once more on that same subject, on the full hardening, to McDonald's paper in the 1920 TRANSACTIONS, in which he has microphotographs, physical tests, hardness tests and all those of various different types of steels quenched directly after the second expansion.

DR. ANCEL ST. JOHN: With respect to Mr. Klopsch's question about the dimensional measurements, it seems to me that for production purposes measurement on one dimension is entirely sufficient. What you are interested in in production is determining the proper time to carry on your quenching process, and any question as to whether the contraction is going to be greater in a longitudinal direction or a transverse direction is entirely beside the point. On the other hand, where it might be of interest to inquire as to whether heavily worked material contracts more proportionally in the direction of the axis of working than it does transversely to that axis, I can see that the two dimensional tests would be of considerable value. But that would be in

the laboratory, and even that I imagine would show that whatever changes took place, even if there were considerable differences in the magnitude thereof, or even in the very remarkable case that we could imagine that there would be a contraction longtitudinally and an expansion transversely, because of crystal grain reorientation, the two effects would take place practically simultaneously, so that we could use either one for the indication in production work.

O. Z. KLOPSCH: I believe I was misunderstood on that point. Dr. Harder talked about getting dimensional changes in cast iron and I was referring to the volume changes as well as dimensional changes. You can get dimensional changes longitudinally, but you cannot get volume changes by taking that one dimension alone.

H. J. FRENCH: Mr. Chairman, I would like to have Dr. Harder's opinion to the statement made by Mr. Woodward in his discussion, a short time ago, to the effect that quenching from the bend in the curve produced minimum distortion. It has been my experience that there are a large number of factors which tend to modify the dimensional changes which are observed in any given steel quenched from a given temperature, perhaps into a given fluid. I would like to have Dr. Harder's reaction, and possibly also a little further discussion from Mr. Woodward on that point.

DR. O. E. HARDER: Mr. Chairman, Mr. French asks a good question. We have done a considerable amount of work along that line, trying to work out in some systematic way the effect of different heat treatments on the dimensional changes. We worked on rods and determined the length change and the change in diameter. To date the work is incomplete and we do not have enough information that I can draw any definite conclusions which would tend to answer Mr. French's question. We have worked on that, but we have not reached conclusions which I would want to give out at this time.

R. W. WOODWARD: In answer to Mr. French's question, in our work on oil hardening steels, which, presumably, show the least change in shape after hardening, we have found that we have gotten the best results from hardening as I stated previously in the paper. The minimum of distortion in the piece is obtained by hardening at that point.

H. J. FRENCH: You would not, then, expand that to include various steels?

R. W. WOODWARD: Yes, I think it would include all steels, too, as far as we know at the present.

A. HUNGELMANN: The question of the comparison of the accuracy of this method compared with the thermocouple method in determining the best point for quenching should be of great interest to the people who have commercialized that latter point. I am referring to the Hump method furnace, and I think it would be very interesting if either a representative or someone who has been a large user of this method would discuss the relation between these two methods.

J. W. HARSCH: It seems to me that this question is similar to the one in which we were involved when the Hump method was first started. At that time we believed that quenching just above the critical point produced the minimum of distortion and the proper structure. We have since found that

quenching at the same point for different types of work will not produce satisfactory results.

DR. S. L. HOYT: In connection with the volume changes or dimensional changes which take place, I should like to ask a question. When do they occur? Do they occur during the quenching treatment or during the tempering treatment which follows? In a small amount of work which I have done in this field I have found that the dimensional changes that occur, occur during tempering. In other words, that the dimensions of the quenched steel may be exactly the same as those of the original steel in the annealed condition, although the thing does not seem to be general for all steels. We have here a rather complex situation, and I can well understand Dr. Harder's reticence in answering a question of that type at this time, until he has studied it further. But certainly in the early stage of the experimentation it would be, in my opinion, desirable to determine and be sure, first, that the temperature of the steel at the moment of quenching is perfectly uniform throughout the whole sample, because a non-uniform temperature there could lead to an absence of shrinkage at Ac_1; thus an expansion at one part could counteract the contraction at another part. And, secondly, I think it would be necessary to follow the dimensional changes in at least two directions, because a shrinkage in one direction may cause expansion in another direction.

It seems to me it is a valuable and important line of investigation which has been opened up here by the paper of Professor Harder and associates, and one which will certainly be extremely interesting, especially in view of the fact that we may expect a further paper dealing with dimensional changes.

DR. O. E. HARDER: Mr. Chairman, I can add just a little along the lines suggested by Dr. Hoyt. We have found dimensional changes in the steels as quenched. I think I am safe in saying that we have found both contraction and expansion in the steels as quenched. We have found further changes on drawing,—and that depends upon the type of steel to some extent, surely; and I think we have found some reversals in the character of the deformation as quenched compared with the material as drawn. I am not quite positive on that subject, but I know we have found changes in dimensions, both on quenching and on drawing.

SAM TOUR: In working on chromium-vanadium steel, there is a question of change in dimensions, irrespective of the particular type of furnace used. In studying changes of dimensions, taking measurements in three directions on blocks and cubes of commercial size, blocks, 2x10x12 inches, and cubes 6 inches on an edge, we have found some peculiar results. The indications are—I will not say that we have positively proved it, but the indications are that the direction of quenching has something to do with the changes of dimensions. On quenching a cube you would normally expect that the changes in dimensions would be the same in all directions. We have found on chromium-vanadium steel that the dimension perpendicular to the surface of the bath on quenching is less than those parallel to the surface of the bath. We have also found an indication that the fiber structure of the steel has something to do with the changes in dimension, the indication being in this steel that con-

(*Continued on Page 520*)

ELASTIC RING FOR VERIFICATION OF BRINELL HARDNESS TESTING MACHINES

By S. N. Petrenko

Abstract

The common methods of verification of Brinell hardness testing machines and the allowable errors in these machines are briefly discussed.

An apparatus designed for accurate verification of Brinell machines is described. The method of verification consists of measuring deflection of a steel ring in the machine to be verified and this deflection is compared with that obtained in a dead-weight Brinell machine. The deflection is measured with a micrometer screw permanently attached to the ring.

An accuracy of ±1/6 of 1 per cent at the maximum load of 3,000 kilograms can be easily obtained with this ring, which is sensitive to a change of load of about 2.5 kilograms.

Introduction

AMONG the mechanical tests which are made in order to ascertain the strength of materials and the uniformity of their properties, the Brinell hardness test is one of the most commonly used.

The advantages of simplicity, rapidity, and comparative nondestructiveness of this test became particularly important with the development, in recent years, of mass production and with the ever increasing tendency toward higher working stresses. This often necessitates the testing of each one, or a large percentage, of finished or unfinished articles.

The Brinell test is probably accompanied by a greater number of errors than other commercially used tests. Some of these errors can easily be minimized or eliminated in a properly conducted Brinell test. The recommendations, based on the results of an investigation recently conducted by the Bureau of Standards, are given in this paper (Appendix).

One of the most serious errors of Brinell testing is due to an

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incorrect load. The methods of calibration of Brinell testing machines are, therefore, discussed here at some length.

Dead Weight Brinell Machine

For precision testing, the Bureau of Standards has designed and built a dead weight machine which is shown in Fig. 1. Three cast iron weights A_1, A_2, and A_3 which were carefully adjusted by the Weights and Measures Division of the Bureau, are supported by a steel frame, A_4. The load due to these weights is applied through a 10-millimeter ball, B, to the specimen, C. By supporting some of the weights so that they do not rest on the frame, different loads can be applied to the specimen. The loads are 500, 1500, 2000, and 3000 kilograms. The error of any one of these loads does not exceed a few hundredths of a pound. To remove the load, the weights are raised by means of the small hydraulic jack, D.

Common Methods of Verification of Brinell Machines

The above described apparatus may be used for verifying other Brinell machines by making a series of indentations in a metal "check specimen," first in this dead weight machine, then in the machine to be verified. The difference in the loads in the two machines can be computed from the difference in the diameters of the indentations. It can be shown that:

$$\Delta P \text{ is approximately} = 2P \times \frac{\Delta d}{d} \quad (1)$$

where P is the correct load
Δ P the error of load
d the diameter of indentation for the correct load P

and Δd the difference between the diameters of the indentations for the load P + ΔP and for the load P. This method gives satisfactory results if the "check specimen" is of uniform hardness. The actual error, however, can be determined only approximately, because the accuracy of this method depends on the properties of the specimen and the degree of approximation is not definitely known.

Another method which is used for the calibration of Brinell testing machines, and which is more accurate than the "check

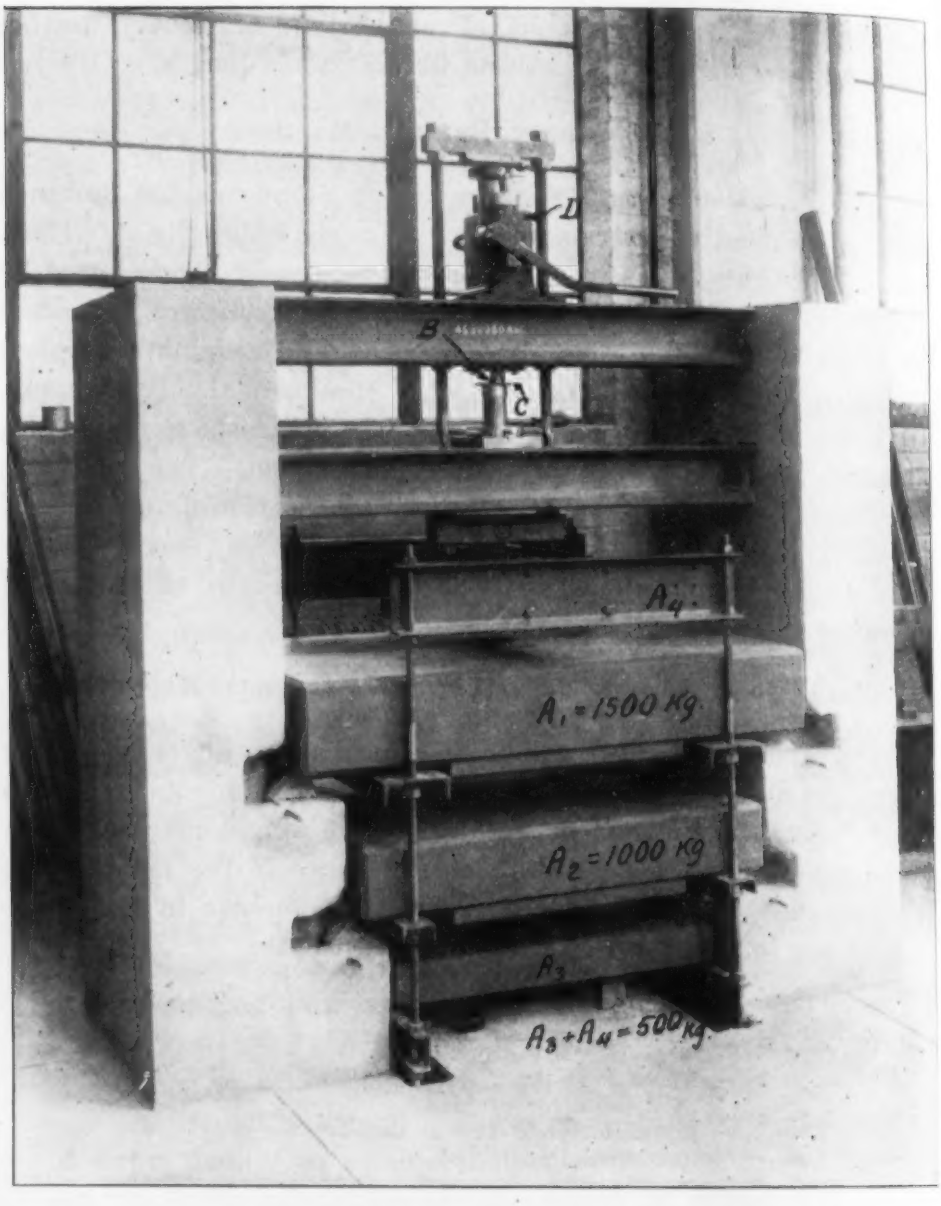

Fig. 1—Dead Weight Brinell Machine. Loads of 500; 1500; 2000 and 3000 Kilograms Can be Obtained in This Machine. These Loads are Correct Within a Few Hundredths of a Pound.

specimen'' method, is by using proving levers, similar to those used for the calibration of other testing machines.[1]

This apparatus is rather heavy and cannot be conveniently shipped where necessary.

[1]J. L. Jones and C. H. Marshall, Proc. A. S. T. M., 1920, p. 392.

The Allowable Error in Brinell Machines

According to the Specification E10-24T of the American Society for Testing Materials, a Brinell machine is satisfactory if the error in load does not exceed three per cent. Let us compare this with other errors which occur in Brinell testing. As was mentioned before, the following approximate relation exists between an increment of load and the corresponding increment of the diameter of indentation.

$$\frac{\triangle d}{d} = \frac{\triangle P}{2P} \quad (2)$$

If the error in the load is equal to ±3 per cent, the corresponding error in the diameter of indentation is ±0.015d. Assume two Brinell machines which comply with the A. S. T. M. Specifications, one of which gives a load three per cent high and the other three per cent low. The difference in the indentations made in these two machines will be 0.03d. If d = 4 millimeters, the difference is 0.12 millimeters. Experience has shown that it is possible and desirable to control the heat treatment of steel of medium hardness within about 20 points Brinell. This corresponds to a variation in the diameter of indentation of about 0.10 millimeters. It is evident that the error of a testing machine must be much less than the change of a variable which the test must discover. According to the A. S. T. M. specifications, the permissible error of load may be about equal to this change.

If it is assumed that the error of the Brinell number, due to the incorrect load, should not exceed 1 per cent, then using formula (2) the corresponding error of load can be determined. This was done for different Brinell numbers from 70 to 700 and the minimum, for this error, was found to be about 20 kilograms. This shows that a Brinell machine should be accurate to at least ±20 kilograms or to ±⅔ of a per cent. The diameter of indentation is usually measured to the nearest 0.01 millimeter. If a similar accuracy were required from the load measuring device of a Brinell machine, the latter should be accurate to about ±10 kilogram or ±⅓ of a per cent at the maximum load of 3000 kilograms.

Elastic Ring for Verification of Brinell Machines

In order to detect the error of load in a machine, the ac-

curacy of a load verifying apparatus ought to be better than the desired accuracy of the machine itself. In order to provide means for an easy and accurate method of measuring the load in Brinell testing machines, there was designed and built at the Bureau of Standards an apparatus shown in Fig. 2. It consists of a ring of hardened steel,[2] A, with a micrometer, B, for measuring the deformation of the ring. The micrometer screw, B, has 40 threads per inch and the circumference of the dial, C, is divided into 100 parts. One division of the dial, therefore, represents 1/4000 of an inch. Under a load of 3000 kilograms the deformation is about 0.030 inch. A vibrating reed, D, attached to the top of the ring, with a small weight E at its end, is used to indicate contact with the micrometer screw. This device was invented by the Cambridge Scientific Instrument Company and used by them on extensometers. Although it is patented in this country, they permitted it to be used on this elastic ring.

To obtain a reading, the reed is deflected and released. While it is vibrating, the micrometer dial is turned until a buzzing sound indicates that the weight, E, is touching the point, F. If the micrometer is properly adjusted for a reading, the buzzing sound will continue for several seconds before the reed ceases to vibrate.

The observations made with this ring have shown that a change of load of 2.5 kilograms (about 6 pounds) is shown by a change of deformation of about 0.1 division of the dial. In other words, the ring is sensitive to a change of load of about 0.1 per cent. The readings of the ring may be easily reproduced within ±0.2 division of the dial, which corresponds to an accuracy of about ±1/6 of a per cent.[3]

Verification of Brinell Machines by the Elastic Ring

These elastic rings may be used to compare the loads applied in a Brinell machine with accurately known loads (which may be obtained in the Bureau of Standards dead weight Brinell machine). The ring is loaded with a known load (500, 1500, 2000, or 3000 kilograms and its deformation determined. This

[2]Satisfactory results were obtained with a steel of the following composition and heat treatment:
C—0.81; Mn—1.11; P—0.021; S—0.019;
Si—0.24; Cr—0.50; W—0.50;
Quenched in oil from 1500 degrees Fahr.;
Tempered at 900 degrees Fahr.
Other steels are being tested.

[3]No change of calibration-constant was noticed during a period of four months.

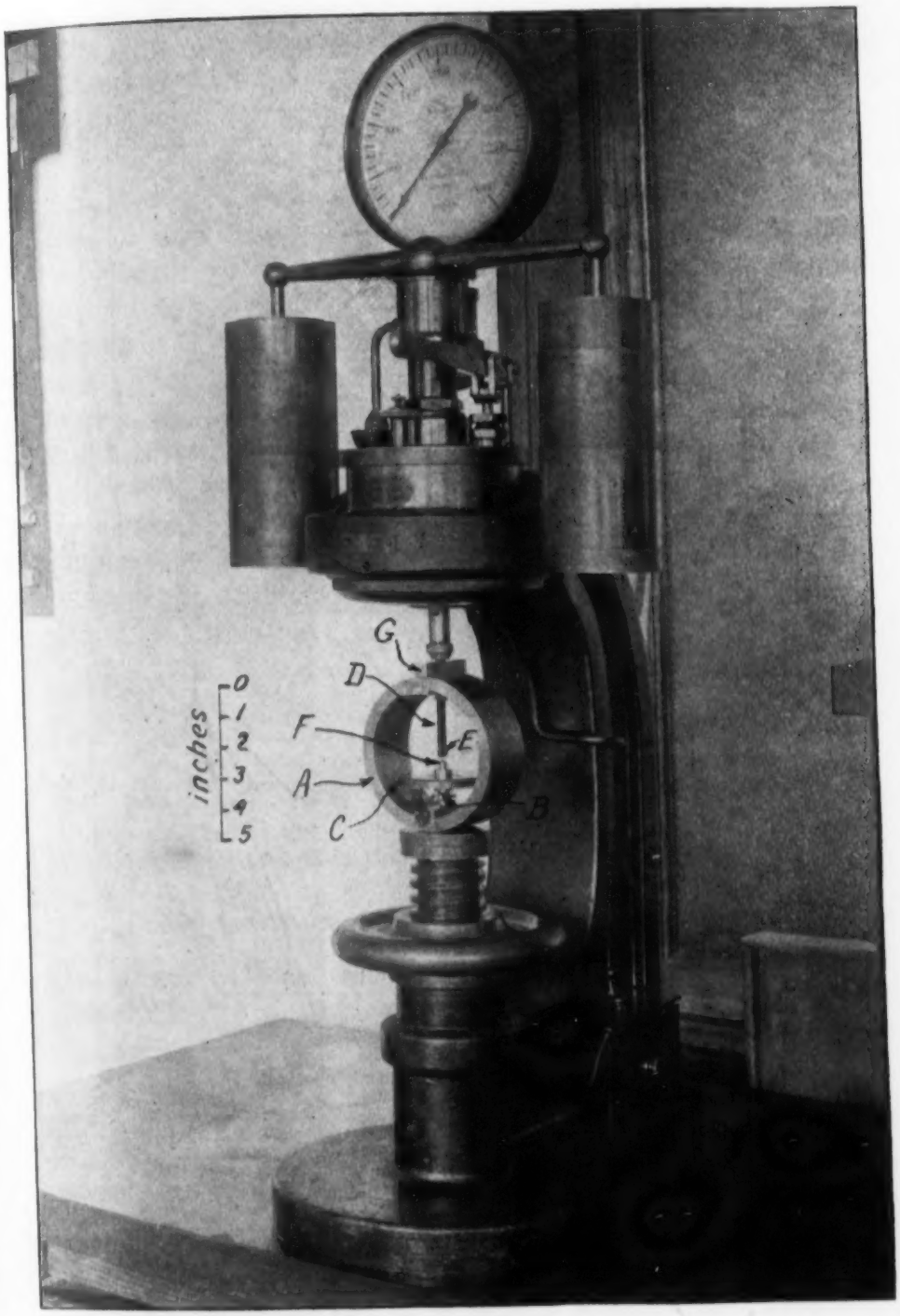

Fig. 2—Elastic Ring in a Brinell Hardness Machine. The Ring is Ready to be Loaded.

deformation is compared with the deformation of the same ring in a Brinell machine which is to be verified. The difference in

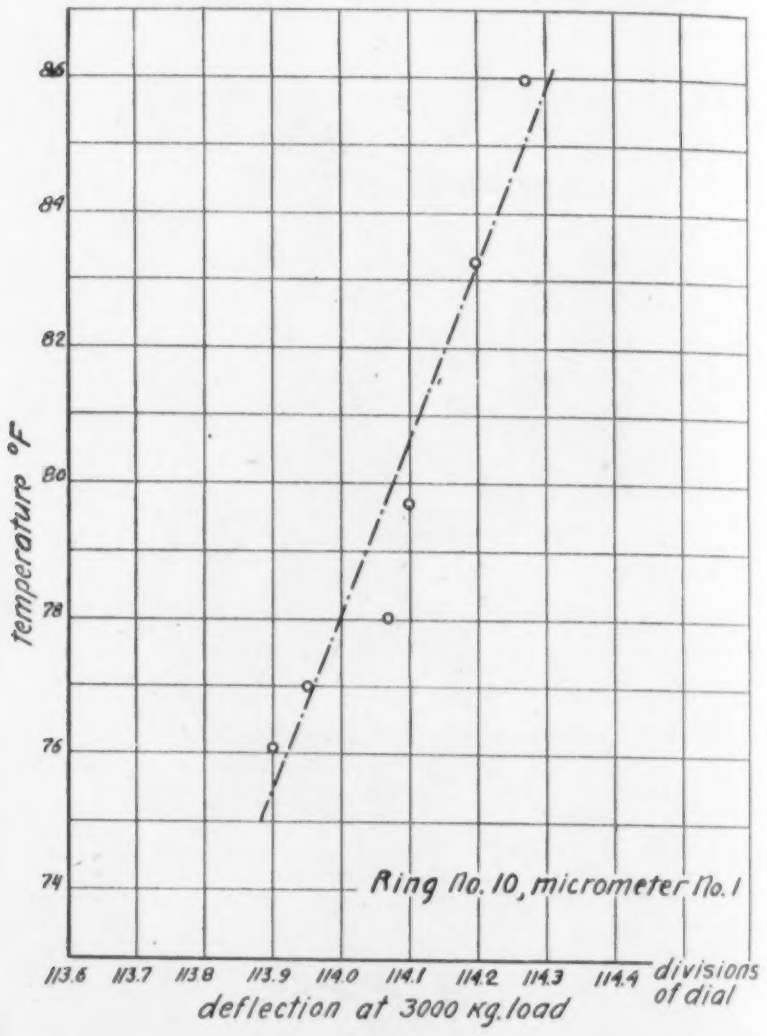

Fig. 3—Effect of Change of Temperature on the Deformation of the Ring. This Effect is Small and May be Disregarded for Work of Ordinary Accuracy.

deflections obtained in two machines, multiplied by the constant of the ring, will give the error of the machine.

The load $P = Cn$ (3)
where C is calibration constant of the ring and n the deformation of the ring in divisions of the dial.

Experience with weighing scales has shown that the use of correction factors or charts is unsatisfactory because frequently

the corrections are not made. If a Brinell machine shows too large a load error, the only safe way is to adjust the machine.

The Effect of Change in Temperature

A few observations made on the rings at temperatures ranging from 75 to 90 degrees Fahr. have shown that the deformation of these rings increases with temperature. Fig. 3 shows the effect of temperature on readings of a ring which was used for these experiments. It will be noted that the differences between the observed points and the straight line are within the errors of observation of the apparatus. The change of deformation due to a temperature change is small.

It is about 0.04 division of the dial for 1 degree Fahr. and can be disregarded in work of an ordinary degree of accuracy. If it is desirable to measure the load accurately, the temperature correction of the calibration constant in the formula $P = Cn$, may be used.

Thus $P = Cn\ [1 - k\ (t - t_o)]$ (4)

In this formula

P = load
C = calibration constant
k = temperature coefficient of the calibration constant
n = deformation of the ring in divisions of the dial.
t = temperature at the time of test
t_o = temperature at the time of test of calibration of ring.

Summary

1. An apparatus consisting of a ring of hardened steel, whose deformation is measured by a micrometer, has been designed for the verification of Brinell hardness testing machines.
2. The apparatus is light (weighs about 5 lbs.), rugged in construction, and simple in operation.
3. The deformation of the ring can be measured under dead weights.
4. The load on the ring, applied by the Brinell machine to be verified, is determined by the formula $P = Cn$ or more accurately $P = Cn\ [1-k\ (t-t_o)]$,
   (for notations see heading "The Effect of Change in Temperature")
   The values of C, t_o, and k can be determined when calibrating the ring.

5. The accuracy of the apparatus is about ±1/5 of a per cent (6 kilograms) at the maximum load of 3000 kilograms and it is sensitive to a change of about 2.5 kilograms throughout its range. A considerably higher degree of accuracy can be obtained by an experienced operator.
6. For small loads such as are used in Brinell testing, this ring has the advantage over a tensile or compressive calibration bar because of its simplicity and greater sensitiveness. For the calibration of large testing machines the advantages of the ring are not so apparent.

Appendix

Recommendations for Making a Brinell Test

The results of experiments conducted by the Bureau of Standards and theoretical considerations, lead to the following conclusions regarding the way in which a Brinell test should be made:

Machine:

1. The machine must be accurate to about ±10 kilogram at the 3000 kilogram load.
2. A machine which has weights, which are displaced during the test, ought to be provided with a device preventing overloading, due to inertia or to other causes.
3. The diameter of the Brinell ball should not differ from 10 millimeters by more than 0.025 millimeters (about 0.001 in.). The deviation of any diameter from the average should be not more than ±0.0025 millimeters (±0.0001 in.).
4. In choosing a ball for the test, it should be remembered that even a small permanent deformation of the ball is likely to result in a considerable change of the radius of its curvature at the spot in contact with the specimen, and, consequently, in an appreciable error of hardness number.

Specimen:

5. The thickness of specimen must be at least 0.35 inches for ductile metals.

For cast iron the thickness ought to be sufficient to prevent crushing of specimen under load.

6. The surface of specimen ought to be carefully ground to permit an accurate measurement of the diameter of indentation.

Method of Making Indentation:

7. The rate of application of load may be between 500 kilograms per second and 100 kilograms per second. Sudden jerks ought to be avoided.
8. The time under load should be in all cases 30 seconds. If the testing machine is well adapted for an immediate release of load, the time may be zero, provided the results of these tests are not directly compared with those obtained when the load is 30 seconds.
9. The distance of the center of an indentation from the edge of the specimen ought to be not less than twice the diameter of the indentation. In the case of cast iron, this distance should be not less than 3.5 diameters.
10. The distance between the centers of two neighboring indentations should be not less than 2.5 times the diameter of the indentation.
11. The angle between the direction of force and the surface of specimen should not differ from 90 degrees by more than 3 degrees.

Measuring Indentation:

12. The error of the apparatus which is used for measuring the indentation should not exceed ±0.01 millimeters.
13. While measuring an indentation, the specimen should be so placed that light is coming in at a right angle to the measured diameter. Artificial light is preferable to daylight.
14. At least two diameters ought to be measured—the maximum and the minimum ones, the average used for determination of Brinell number.

THE EFFECT OF MANGANESE, SILICON AND PHOSPHORUS ON THE PEARLITE INTERVAL

By B. Kjerrman

Abstract

The "point" Ac_1 occurs over a range of temperatures instead of at a definite temperature in steel containing manganese, silicon, or phosphorus. The effect of these elements upon this range is experimentally determined by the change in electrical resistance on heating. Previous heat treatment which tends toward homogeneity of structure reduces the range caused by manganese, but does not affect the range caused by silicon or phosphorus. Manganese lowers the range, silicon raises it. This effect may be explained on the assumption that, at the same temperature, manganese and silicon are, respectively, more or less soluble in austenite than ferrite. There may result from these differences in solubility, depending on the rate of cooling at various periods, non-homogeneity of the pro-eutectoid ferrite with respect to its manganese or silicon content, as well as differences in composition between pro-eutectoid ferrite and the lamellar ferrite of the pearlite. Steel sufficiently high in both manganese and silicon shows two separate ranges as determined by the resistance method.

IN pure iron-carbon alloys, the simultaneous change of *alpha* iron to *gamma* iron and the solution of Fe_3C in *gamma* iron on heating, termed Ac_1, occurs at 735 degrees Cent. (1355 degrees Fahr.) and, according to the conventional equilibrium diagram, it occurs at a fixed and definite temperature.

Manganese is known to lower Ac_1,[1] and silicon to raise it.[2] While thermal analysis shows that Ac_1 occurs over a range of temperatures, and there is argument as to whether the beginning, maximum, or end of the range is the important temperature, yet Ac_1 is commonly thought of, even in commercial steels containing manganese and silicon, as a definite temperature rather than a

[1]Hoyt, S. L., Metallography, Part 2, Metals and Common Alloys, pp. 191-192, 1921.

[2]Meacham, F. L., Effect of Silicon on the Thermal Critical Points of Steel, Transactions, American Society for Steel Treating, Vol. 4, 1923, p. 635.

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A paper by B. Kjerrman, research fellow, Bureau of Standards, Washington, D. C.

range or interval. The failure of thermal analysis to show the change at a definite temperature is usually attributed to the reaction starting in some portions of the specimen before it does in others, due to temperature differences in the specimen, or, at a rapid rate of heating, to lack of time for the reaction to proceed to completion. If this idea were correct, once the Ac_1 change were started it would complete itself at constant temperature, if enough energy were supplied to provide the heat absorbed in the reaction. If, then, the system is held at a temperature slightly above that at which the beginning of the reaction can be noted, the reaction should go to completion.

If, on the other hand, either the *alpha* to *gamma* change or the solution of Fe_3C in the *gamma* is progressive over a range of temperatures, the reaction would not go to completion, but various stages of equilibrium could be attained with *alpha* iron, *gamma* iron and Fe_3C in contact at temperatures above the beginning of Ac_1.

Jones[3] has noted a variation in the temperature of Ac_1, according to the previous treatment of the material, and, by "soaking" within the range and cooling, has, on the next heating, been able to show a doubling of the point. He finds that a range, rather than a single temperature for Ac_1 is common to a great variety of alloy steels, and uses the word "range" in the title of his paper.

Swinden[4] and Scott[5] have also shown variations in Ac_1 in alloy steels, depending on the previous treatment of the steel.

A temperature interval at Ac_1 has also been noted by Lundgren.[6] He claims that the pearlite transformation occurs at a definite temperature, with a sharp arrest in the case of lamellar pearlite, but that when the pearlite is globular, Ac_1 occurs over a temperature interval. This, he states, is more marked in chromium than in carbon steels, though the interval occurs in both.

The writer[7] has described the Ac_1 interval in connection with

[3]Jones, J. A., The Ac_1 Range in Alloy Steels, *Journal*, Iron and Steel Institute, Vol. 107, 1923, p. 439.

[4]Swinden, T. A., Study of the Constitution of Carbon-Molybdenum Steels, Iron and Steel Institute, Carnegie Scholarship Memoirs, Vol. 5, 1913, p. 100.

[5]Scott, H., Effect of Rate of Temperature Change on Transformations in an Alloy Steel, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 62, 1920, p. 689.

[6]Lundgren, A., Jernkontorets Annaler, 1920, p. 16.

[7]Kjerrman, B., Jernkontorets Annaler, 1921, p. 317.

work on the soft annealing of steel. In this work the Ac_1 interval was observed to be reduced in both range and temperature by heating at slower rates. In this early work the interval was thought to decrease with higher carbon content and to disappear at about 0.50 per cent carbon, but in the later work, about to be described, done with improved apparatus, it has been found even in hypereutectoid steel.

Theory of the Ac_1 Interval

According to the phase rule, in a condensed, two-component system in which the effect of pressure is not considered, three phases can be in equilibrium only at an invariant point; the system has no degrees of freedom and the temperature is definitely fixed. In the pure iron-carbon system, then, *alpha* iron, *gamma* iron, and cementite can be in equilibrium only at a fixed temperature, the Ac_1 as long as we assume that pressure has no effect.

However, since *alpha* and *gamma* iron have different specific volumes, the pressure in the system does change as the transformation progresses, and an Ac_1 interval is theoretically possible, even in the pure iron-carbon system, though it is doubtful if present apparatus is adequate to measure the interval.

In commercial steels, manganese and silicon are present in addition to the carbon. If these be dissolved in ferrite, the solution forms a single phase, but there are four components present. Hence the phase rule no longer demands that the Ac_1 transformation occur at an invariant point, but logically calls for it to occur over a temperature interval.

If the elements dissolved in the ferrite are not uniformly distributed therein, the transformation can be still further affected, as will be brought out below.

It is believed that equilibrium is set up, not only in respect to carbon, but to other elements, such as manganese and silicon, which are assumed to be, at the same temperature, respectively, more and less soluble in austenite than in ferrite. The interchange of manganese between *alpha* and *gamma* iron is probably slower than that of carbon. As the manganese concentration changes, the solvent power of *gamma* iron for cementite also changes.

If complete diffusion of carbon and manganese in austenite

is brought about by sufficiently long heating above Ac_3, then, on cooling through Ar_3, pro-eutectoid ferrite is precipitated, and the residual austenite steadily becomes more concentrated in manganese, as the tendency will be to precipitate relatively manganese-free ferrite first, near the Ar_3 point for manganese-free iron. As the temperature falls, the amount of manganese precipitated with the ferrite will increase, and the last to form, that coming out just above Ar_1, will be richest in manganese.

The lower the carbon content of the steel, the more ferrite will be precipitated. When the last ferrite comes out just above Ar_1, the residual austenite will be of a decidedly higher manganese content than the original austenite.

As pearlite starts to precipitate, the manganese content of the austenite still remaining will rise still higher, because the cementite is relatively free from manganese, but its precipitation uses up some of the iron in the austenite.

The final result after cooling through Ar_1 is a mixture of ferrite of varying degrees of purity, according to the temperatures at which it came out, and of lamellæ of cementite and manganese-rich ferrite. Hence the steel is segregated on a microscopic scale. By very slow cooling from Ar_3 to Ar_1, diffusion may take place and the ferrite segregation be overcome. But the pearlite may not be uniform if the cooling at and below Ar_1 is rapid, with the result that, for example, there may exist thin lamellæ at one point and thick ones at another, and the manganese content of the ferrite of the lamellæ may vary. Depending on the rate of cooling at various periods, we may then have (a) pro-eutectoid ferrite homogeneous in composition through diffusion, and pearlite whose ferrite lamellæ also have that same composition, (b) ferrite homogeneous, but pearlite with ferrite lamellæ of a different composition, (c) ferrite nonhomogeneous throughout; or they may be termed:

a—ferrite and pearlite diffused,
b—ferrite diffused, pearlite segregated,
c—ferrite and pearlite segregated.

On heating these three types of material, cementite will start to go into solution at different temperatures, depending on the composition of the ferrite in contact with it. The more highly segregated the steel, the higher the manganese near the cementite and the lower the temperature at which solution of cementite

will begin. For this reason, variations in heat treatment which affect the degree of segregation in ferrite or pearlite affect the Ac_1 interval, and the interval may in turn serve to indicate the segregation. The more nearly homogeneous the ferrite and the pearlite, as, for example, after long annealing, the higher the beginning of Ac_1 and the shorter the interval.

If now we consider an iron-carbon-silicon alloy, free from manganese, we find marked differences from the case where manganese was the third element. The precipitation of pro-eutectoid ferrite at Ar_3 appears to start with a silicon-rich ferrite, as though silicon were more soluble in ferrite than in austenite. Oberhoffer[8] has recently published a diagram which indicates that alloys of iron and silicon with less than about 5 per cent silicon, on cooling from the *gamma* field, will first separate out material rich in silicon, and as the temperature falls, the material separating will be more nearly pure iron. We may then assume that as an iron-silicon-carbon alloy cools through Ar_3 the austenite becomes progressively lower in silicon, and the last of the pro-eutectoid ferrite is low in silicon.

As pearlite precipitates, some of the iron of the residual austenite is used up in forming cementite, and the ferrite of the pearlite lamellæ is higher in silicon than the neighboring, most recently deposited, pro-eutectoid ferrite. With manganese, the last of the pro-eutectoid ferrite is higher in manganese—less nearly pure iron. With silicon, the last of this ferrite is lower in silicon and more nearly pure iron.

On heating to Ac_1 cementite starts to dissolve respectively in manganese-rich and silicon-poor austenite, formed from those varieties of ferrite. In the first case, solution starts below the Ac_1 point of the pure iron-carbon alloys. If the manganese content is not too high (not much over 1 per cent in about 0.30 per cent carbon steel) Ac_1 ends at the pure iron-carbon Ac_1 temperature. The starting temperature depends on the manganese content of the austenite formed from the ferrite near the cementite and on its uniformity of manganese content. Cementite starts to go into that austenite with the highest manganese content. At the end, practically manganese-free austenite is the solvent. If the manganese content is high, both the start and the end of

[8]Oberhoffer, P., Zur Kenntnis der Eisen—Silizium—Legierungen, *Stahl und Eisen*, Vol. 44, 1924, p. 979.

Ac_1 may be depressed. In the second case, cementite starts to go into solution in austenite formed from silicon-poor ferrite. If this austenite is practically silicon-free, Ac_1 will start at the pure iron-carbon Ac_1 temperature, otherwise the beginning will be raised somewhat. At the end, silicon-rich austenite is the solvent, and hence the end of the interval varies in steels of varying silicon content. The effect of phosphorus is similar to that of silicon.

Manganese, then, tends to extend Ac_1 below the temperature at which it occurs in the pure iron-carbon system, while silicon or phosphorus tends to extend it above that temperature. Large amounts of manganese depress the end, and large amounts of silicon raise the beginning. A sufficiently sensitive method of determining Ac_1 should, then, show a splitting of the Ac_1 interval into two intervals, one due to manganese and one to silicon, in steels high in both elements.

Apparatus Used in Experimental Work on the Ac_1 Interval

The pearlite interval was studied by the electric resistance method which has been described by Boudouard,[9] Saldau,[10] Enlund,[11] and the writer.[12].

The resistance measurements were made on specimens while heated in nitrogen. The nitrogen was purified by passing it through a train containing crushed charcoal heated to 800 degrees Cent. (1472 degrees Fahr.), soda lime, calcium chloride (to remove the bulk of the oxygen present as impurity in the nitrogen, and to remove carbon dioxide and moisture formed), alkaline pyrogallol (to remove the last traces of oxygen), ammoniacal cuprous chloride and copper (to remove carbon monoxide), potassium dichromate in dilute sulphuric acid (to remove sulphur dioxide), followed by concentrated sulphuric acid and phosphorus pentoxide to dry the gas.

The specimen was heated in a silica tube of 2.8 centimeters inside diameter by 3.0 centimeters outside diameter by 70 centi-

[9]Boudouard, O., Determination of the Points of Allotropic Changes of Iron and Its Alloys by the Measurement of the Variations in the Electric Resistance, *Journal*, Iron and Steel Institute, 1903, I, p. 299.

[10]Saldau, P., Apparatus for the Measurement of Electric Resistance of Material in the Solid State at High Temperatures and Its Application to the Determination of the Critical Points of Iron and Steel. Iron and Steel Institute, Carnegie Scholarship Memoirs, Vol. 7, 1916, p. 195.

[11]Enlund, B. D., Jernkontorets Annaler, 1918, p. 195.

[12]Kjerrman, B., work cited, ft. note 7.

meters long within an electric furnace. The furnace was specially wound to give a uniform temperature over the 3-centimeter test length of the specimen, and was regulated by two rheostats in parallel, which were adjusted in accordance with the readings of a shunted milliammeter. The steel specimen, 0.5 x 0.5 x 6 centimeters nominal dimensions, was prepared by milling, and was finished by hand on metallographic polishing papers. Exact dimensions were measured with a micrometer. The specimen was placed within a porcelain tube 1.0 centimeter inside diameter x 1.4 centimeters outside diameter x 6.0 centimeters, which was centered within the larger tube by sheet nickel rings. The resistance was measured by observing the voltage drop over a 3-centimeter test length when a current of exactly 5 amperes was passed through the specimen from a 4-volt storage battery. The current was controlled by a rheostat and a shunted milliammeter, and was led to the specimen by 1.5-millimeter diameter copper leads riveted to the ends of the specimen.

The voltage drop over the 3-centimeter test length was measured by a millivoltmeter of 300 ohms internal resistance connected to 1-millimeter nickel leads riveted to the specimen at two slots 3 centimeters apart and 1.5 centimeter from the ends of the specimen. The slots were made by sawing, the nickel wires inserted in the slots and that edge of the slot away from the test length was peened down so as to hold the wire snugly.

The nickel leads afforded a method of checking the uniformity of temperature of the specimen. By switching off the 5-ampere current after each voltage reading, any difference in temperature at the two junctions of the nickel leads and the specimen would evidence itself as a thermo-electric current. No voltage reading was used unless the millivoltmeter showed a zero reading with the current off.

The temperature of the specimen was read by a platinum-platinum-rhodium couple 0.5 m. m. in diameter, wired to the specimen with nickel wire, both couple and wire, however, being separated from the specimen by a mica sheet for insulation. The cold junctions were held at 20 degrees Cent. in two *Thermos* bottles. The temperature was read on a millivoltmeter of 300 ohms internal resistance. The couple was compared with one calibrated by the Statens Provingsanstalt, Stockholm, and found to agree with it. The thermocouple and voltage leads were insulated

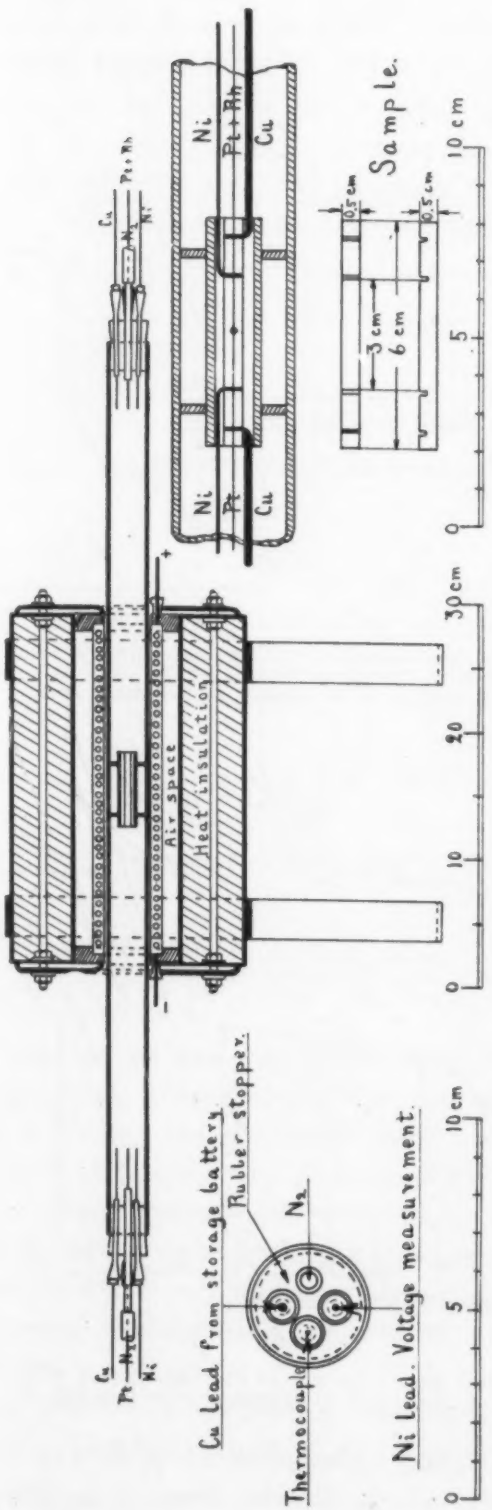

Fig. 1—Arrangement and Details of Apparatus Used in High-temperature Resistance Tests.

by small quartz tubes. The copper lead wires were not insulated. The various wires were led into the quartz tube through small

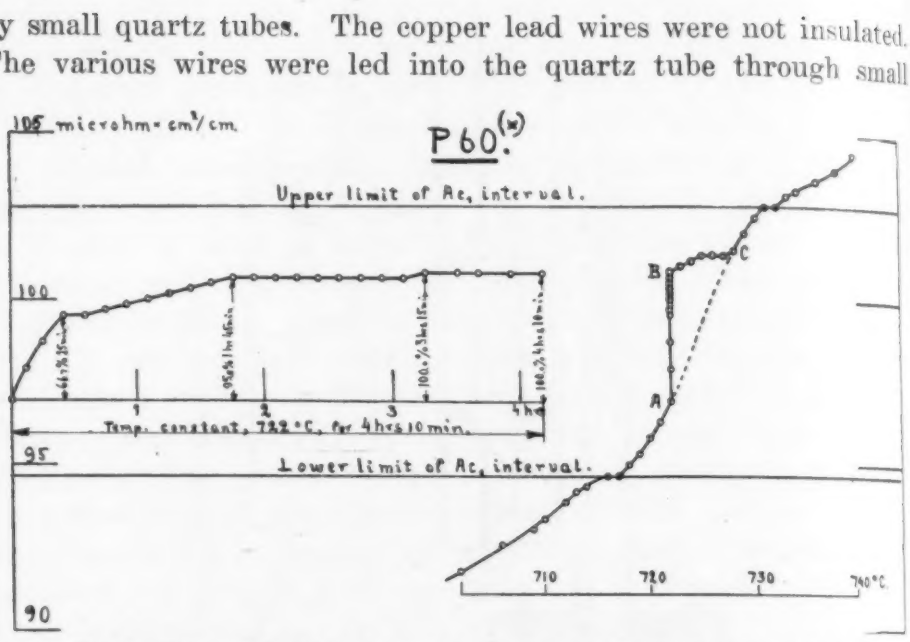

Fig. 2—Change of Resistance in a 0.35 Per Cent Carbon Steel at Usual Rate of Heating Except for the Part of the Curve from A to B. Held at Constant Temperature 4 Hours and 10 Minutes from A to B. Change in Resistance During that Time Shown at Left. (See also Fig. 6.)*

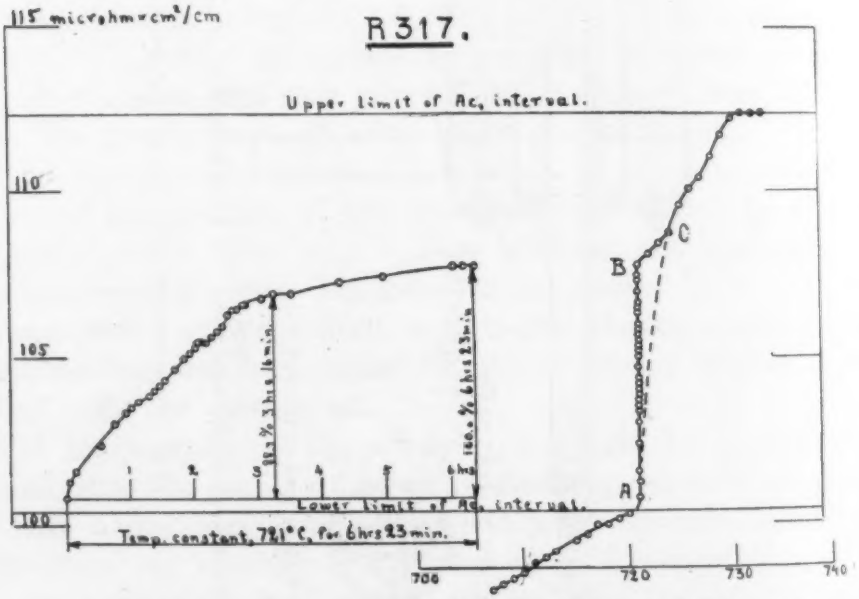

Fig. 3—Same as Fig. 2 for a 1.15 Per Cent Carbon Steel Held at Constant Temperature 6 Hours and 23 Minutes. (See also Fig. 9.)

rubber stoppers in glass tubes inserted in larger rubber stoppers. The purified nitrogen was led in through a glass tube at one end, and out through a second tube at the other end to a bubble

tube filled with concentrated sulphuric acid. The essential portions of the apparatus are shown in Fig. 1.

With everything in place, the purified nitrogen was passed through the system for two hours, and heating was begun. The rate of heating at or near the Ac_1 interval was slow, about 1 degree Cent. in five minutes, and two observations were made at each temperature. Voltage readings could be duplicated to ± 0.01

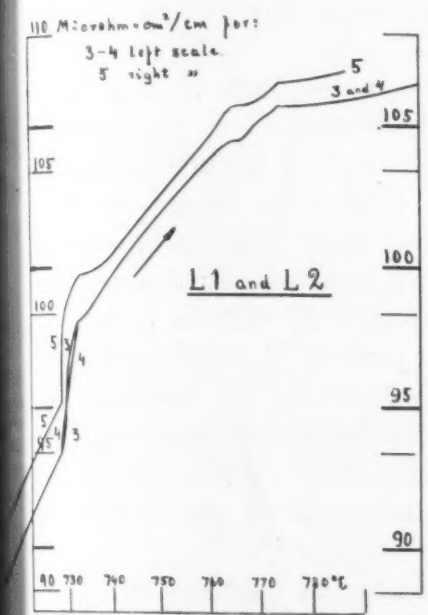

Fig. 4

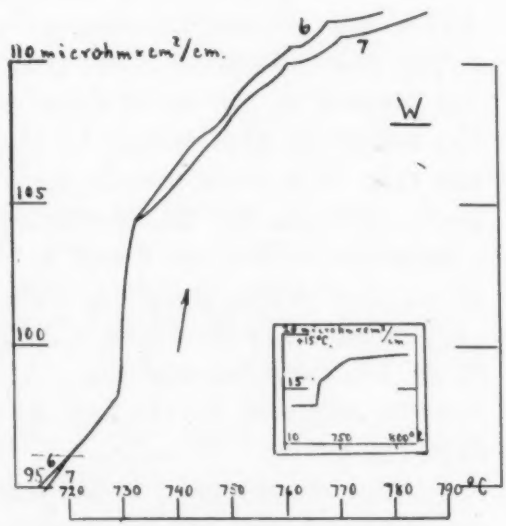

Fig. 5

Fig. 4—Pearlite Interval in Steel of 0.35 Per Cent Carbon, 0.04 Per Cent Manganese and 0.09 Per Cent Silicon. Fig. 5—Pearlite Interval in Steel of 0.40 Per Cent Carbon, 0.02 Per Cent Manganese and 0.13 Per Cent Silicon. Inset—Resistance at 15 Degrees Cent. after Quenching from Temperatures Shown.

millivolt. If a run on the same specimen were repeated without disturbing the specimen, temperatures for the same millivoltage agreed to 1 degree Cent., but duplicate runs on different specimens of the same steel might vary 3 degrees Cent. Most of the runs on the same material were made without disturbing the specimen. In some cases, as a rough check, the specimens were quenched in water from various temperatures and the resistance measured at 15 degrees Cent. Microscopic examination was made on the quenched specimens.

The observed points for specimens Number P-60 and R-317* are plotted in Figs. 2 and 3. In most of the other figures several

*This number and the corresponding numbers in succeeding figures refer to the sample identification marks on the Steel specimens.

curves are shown and the observed points have been omitted, since plotting the points would blur the curves.

Evidence for the Existence of an Ac_1 Interval

If the Ac_1 transformation were capable of completion at the definite temperature, long holding at, or slightly above, the temperature at which the transformation is first evident, should bring about the full change of resistance due to the transformation.

That this is not the case is shown by Figs. 2a and 3a, in which are plotted the change of resistance of a hypo- and a hypereutectoid carbon steel treated in such a manner. The dotted portion of the curve from A to C of Figs. 2a and 3a shows the resistance that would be obtained when running the test at the rate of heating usually used (five minutes per degree centigrade through the transformation range), as will be evident by comparison with Figs. 6 and 9. The part A, B, of the full curve shows that when specimen P60 was held at 722 degrees Cent. (1330 degrees Fahr.) for 4 hours its resistance increased from 97 to 101 microhm/cm²/cm. Approximately 66 per cent of this increase occurred in the first 25 minutes and 96 per cent in the first 1¾ hours.

Similarly specimen R-317 was held at 721 degrees Cent. (1330 degrees Fahr.) more than 6 hours, during which time the resistance rose from 101 to 106 microhm/cm²/cm. About 90 per cent of the change occurred in the first 3 hours. The longer time for R-317 is due to the greater amount of cementite. The resistance appears to have become constant at the end of the heating periods at constant temperature which were used, and the slope of the curve indicates that an infinitely long heating at constant temperature would not dissolve all the pearlite.

As soon as the temperature of these specimens that had been held a long time at constant temperature was raised pearlite again went into solution, but at a slower rate (B, C), until at C the specimens had the same resistance they would have had if the heating had all been done at a constant rate, instead of pausing at 721 or 722 degrees Cent.

Thus there appears to be, at Ac_1, a gradual solution of pearlite depending on the temperature. If the heating is interrupted, apparent equilibrium is produced without all the pearlite

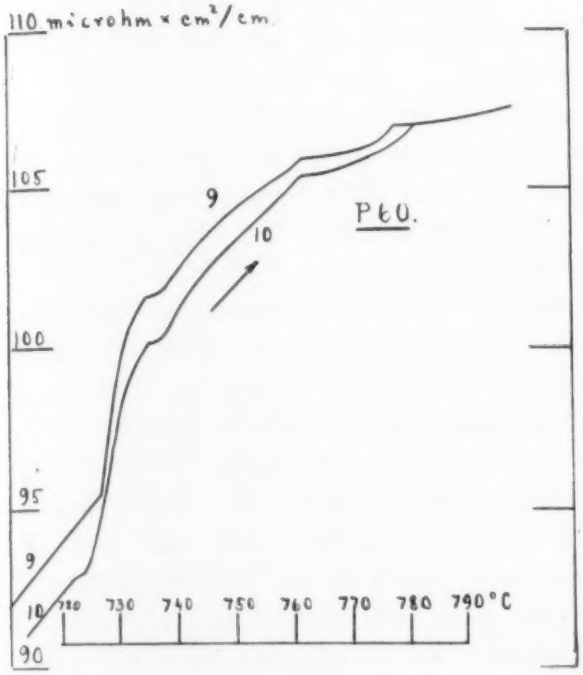

Fig. 6—Pearlite Interval in Steel of 0.35 Per Cent Carbon, 0.47 Per Cent Manganese and 0.10 Per Cent Silicon. (See also Fig. 2.)

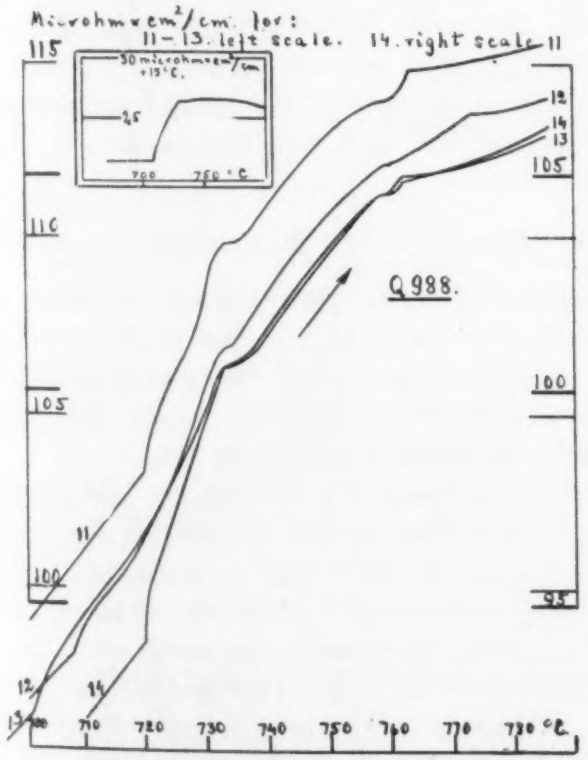

Fig. 7—Pearlite Interval in Steel of 0.31 Per Cent Carbon, 1.07 Per Cent Manganese and 0.33 Per Cent Silicon. Inset—Resistance at 15 Degrees Cent. after Quenching from Temperature Shown.

going into solution, so that Ac_1 appears to be a range or interval rather than a point.

If, during the interval, heating is interrupted and the specimen held at constant temperature, solution of pearlite will go on for a time, but will then slow down and finally cease, and equilibrium will be established for that exact temperature. As a comparison of the curves for P-60 and P-317 (Figs. 2 and 3) shows, the lower the carbon, the sooner equilibrium is established.

Manganese lowers Ac_1—silicon raises it. That is, silicon is more soluble in ferrite than in austenite. Hence, while continued diffusion of manganese from *alpha* to *gamma* iron and increased solubility of Fe_3C goes on at constant temperature within Ac_1, no such diffusion of silicon takes place. The Ac_1 interval of steel K-3, with 0.30 per cent carbon, 0.02 per cent manganese, 1.21 per cent silicon, was found to be 738-752 degrees Cent., although the interval ran from 106.2-112.0 microhm/cm²/cm. On holding at 741 degrees Cent. (1363 degrees Fahr.) for an hour, the resistance changed only from 108.3 to 108.6 microhm/cm²/cm. All this increase took place during the first 40 minutes. No further solution of pearlite took place. Contrast this with P-60, Fig. 2, of about the same carbon content, but with 0.47 per cent manganese and only 0.10 per cent silicon, in which, in the first hour, at constant temperature, the resistance changed from 97 to 100 microhm/cm²/cm. and, on longer heating, continued to increase to 101.

Ac_1 in Steels Low in Manganese and Silicon

In the absence of manganese, silicon, or other alloying element, Ac_1 should occur at a definite temperature, or at least over a very small range. Also, since the pro-eutectoid ferrite will always be pure, segregation will be absent and previous heat treatment should be without effect on Ac_1.

All of the low-manganese, low-silicon specimens (numbers 1 to 7, Table I, and Figs. 4 and 5) indeed show that previous heat treatment, aimed to diffuse or to segregate the ferrite and pearlite, is quite without effect. The short interval for Ac_1, to be expected in these same specimens, appeared only in two of the four steels examined (Nos. 3 to 7, Table I). In these two steels the Ac_1 range extended over only 4 degrees Cent., but in steels 1 and 2 (which also gave the same interval, irrespective of previ-

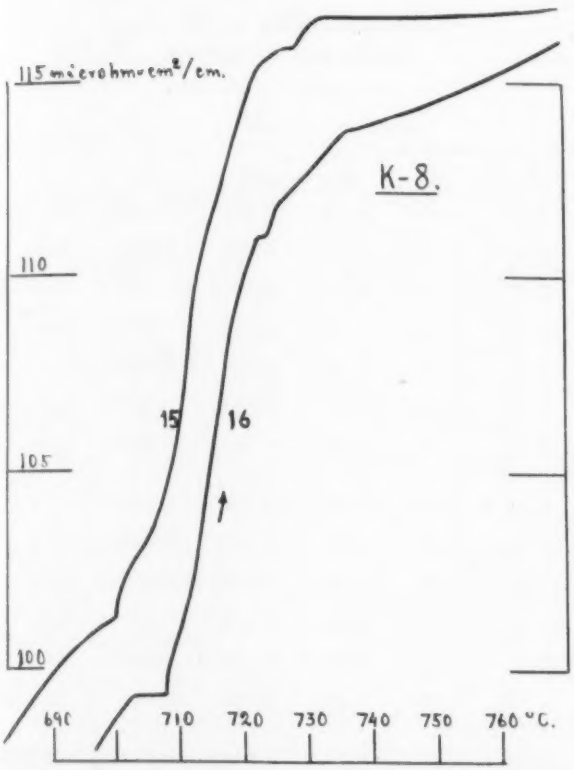

Fig. 8—Pearlite Interval in Steel of 0.57 Per Cent Carbon, 1.62 Per Cent Manganese and 0.08 Per Cent Silicon.

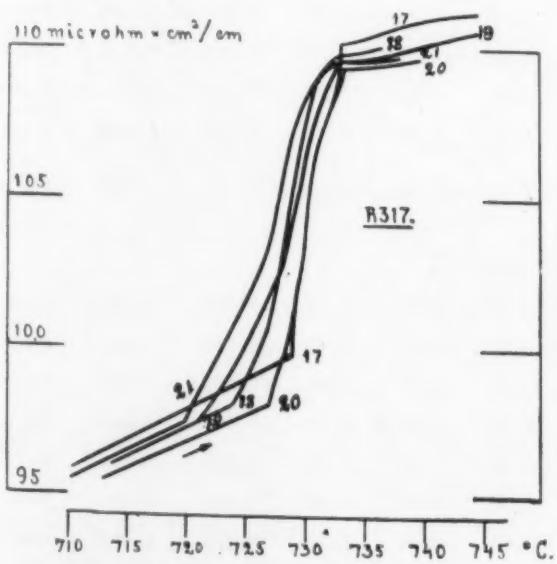

Fig. 9—Pearlite Interval in Steel of 1.15 Per Cent Carbon, 0.35 Per Cent Manganese and 0.17 Per Cent Silicon. (See also Fig. 3.)

Table I
Summary of Results

Run	Identification Mark	Figure No.	Composition in Per Cent C	Mn	Si	P	S	Kind
1	...	..	0.30	0.02	0.04	0.002	0.002	Electrolytic iron melted and carburized
2	...	..	0.35	0.13	0.03	0.008	0.025	Basic O. H. iron remelted and carburized
3	L-1	4	0.35	0.04	0.09	0.061	0.010	Lancashire iron melted and carburized
4	L-1	4	0.35	0.04	0.09	0.061	0.010	Lancashire iron melted and carburized
5	L-2	4	0.35	0.04	0.09	0.061	0.010	Lancashire iron melted and carburized
6	W	5	0.40	0.02	0.13	0.018	0.006	Sponge iron melted and carburized in crucible
7	W	5	0.40	0.02	0.13	0.018	0.006	Sponge iron melted and carburized in crucible
8	P-60	..	0.35	0.47	0.10	0.023	0.027	Acid O. H.
9	P-60	6	0.35	0.47	0.10	0.023	0.027	Acid O. H.
10	P-60	6	0.35	0.47	0.10	0.023	0.027	Acid O. H.
11	Q-988	7	0.31	1.07	0.33	0.018	0.027	Acid O. H.
12	Q-988	7	0.31	1.07	0.33	0.018	0.027	Acid O. H.
13	Q-988	7	0.31	1.07	0.33	0.018	0.027	Acid O. H.
14	Q-988	7	0.31	1.07	0.33	0.018	0.027	Acid O. H.
15	K-8	8	0.57	1.62	0.08	0.013	0.024	Basic O. H. remelted, C and Mn added
16	K-8	8	0.57	1.62	0.08	0.013	0.024	Basic O. H. remelted, C and Mn added
17	R-317	9	1.15	0.35	0.17	0.020	0.024	Basic electric (induction)
18	R-317	9	1.15	0.35	0.17	0.020	0.024	Basic electric (induction)
19	R-317	9	1.15	0.35	0.17	0.020	0.024	Basic electric (induction)
20	R-317	9	1.15	0.35	0.17	0.020	0.024	Basic electric (induction)
21	R-317	9	1.15	0.35	0.17	0.020	0.024	Basic electric (induction)
22	K-4	11	0.37	0.05	0.42	0.020	0.014	Steel W remelted with ferro-silicon
23	K-4	11	0.37	0.05	0.42	0.020	0.014	Steel W remelted with ferro-silicon
24	K-3	12	0.30	0.02	1.21	0.003	0.006	Electrolytic iron melted with charcoal and ferro-silicon
25	K-3	12	0.30	0.02	1.21	0.003	0.006	Electrolytic iron melted with charcoal and ferro-silicon
26	R-93	13	0.48	0.76	1.86	0.029	0.020	Basic electric (induction)
27	R-93	13	0.48	0.76	1.86	0.029	0.020	Basic electric (induction)
28	L-989	14	1.05	0.26	1.39	0.026	0.026	Acid O. H.
29	L-989	14	1.05	0.26	1.39	0.026	0.026	Acid O. H.
30	L-989	14	1.05	0.26	1.39	0.026	0.026	Acid O. H.
31	K-6	15	0.23	0.01	0.035	0.990	0.006	Lancashire iron melted with charcoal and yellow phosphorus
32	K-6	15	0.23	0.01	0.035	0.990	0.006	Lancashire iron melted with charcoal and yellow phosphorus
33	K-6	15	0.23	0.01	0.035	0.990	0.006	Lancashire iron melted with charcoal and yellow phosphorus

Table I—(Continued)

Heat Treatment	Ferrite D=diffused S=segregated	Pearlite	Ac_1 interval Degrees Cent.	Ac_3
.....		D and S	718–733	..*
.....		D and S	720–733	..*
850° C. air	S	S	728–732	773
780-700° C. furnace slowly and then more rapidly	D	S	728–732	773
680-720° C., 18 hrs.	D	D	728–732	773
778° C. air	S	S	729–733	769
720-735° C. 12 hrs. cooled to 600° C., reheated to 715-717° C. 1½ hrs. as rolled	D	D	729–733	771
	S	S	721–733	..*
1000° C. 2 hrs., cooled to 600° C. in 24 hrs.	D	D	727–735	778
850-640° C. in 20 min., then to room temperature	S	S	722–735	782
750-770° C. 12 hrs. to 650° C. slowly	D	D	720–733	763
685-640° C. in 18 min., then to room temperature	S	S	708–733	773
762-680° C. slowly, heated to 725° C., slow cooled to 680° C., then rapidly cooled	D	S	701–733	762
1000° C., water quenched, heated quickly to 650° C.	D	D	720–733	762
800° C. air	S	S	700–726	732
650-690° C., 14 hrs.	D	D	708–722	736
annealed at 760° C. and very slowly cooled	.	D	729–733	..*
1000-650° C. in 20 min.	.	S	724–733	..*
annealed 725° C., slow cooled to 697° C., then rapidly	.	S	721–733	..*
annealed 760° C., slowly cooled to 710° C., held at 705-710° C. 11 hrs., then cooled to room temperature	.	D	727–733	..*
Same as 19	.	S	720–733	..*

			1st or low Ac_1 (Mn)	2nd or high Ac_1 (Si or P)	Extra Points	Ac_3
800° C. rapidly cooled	S	S	728–733	736–744	.....	780
annealed 733° C. 5 hrs.	D	D	729–733	735–744	.....	782
828° C. air	S	S	.....	738–752	.....	802
annealed 713-720° C. 5 hrs.	D	D	.....	739–752	.....	799
annealed 700-710° C. 15 hrs.	D	D	725–732	736–743	755–757	774
860° C. air	S	S	718–731	733–744	760–762	783
800° C., water drawn at 675° C.	.	D	730–733	740–748	.....	..*
773 to 600° C. in 3 min.	.	S	710–713	730–753	.....	..*
As shown in heating curve 29 and cooled to room temperature	.	S	719–721	730–731	740–759	..*
800° C. air	S	S	.....	736–754	.....	792
annealed 700-730° C., 24 hrs.	D	D	.....	738–752	.....	781
870° C. air	S	S	.....	737–754	.....	794

*Not recorded.

ous heat treatment), the range is large, about 15 degrees Cent. The author can give no explanation for these large ranges when the theory calls for a small one. The widely different grain size

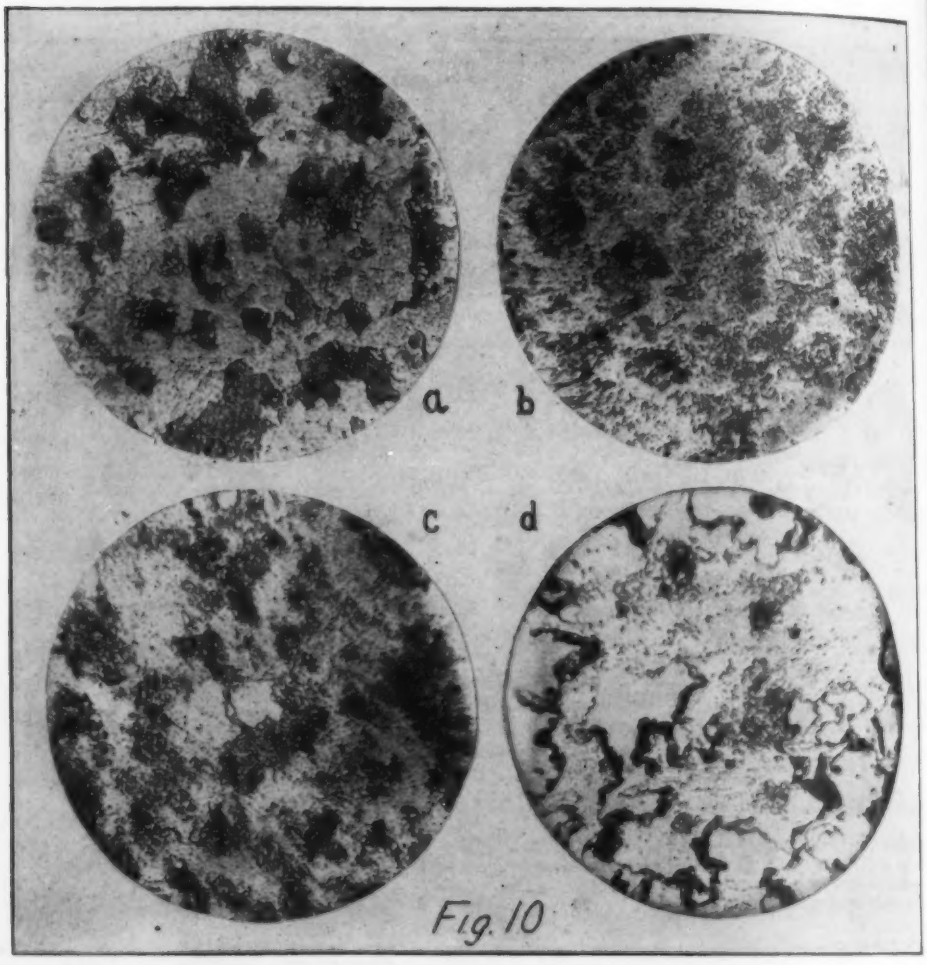

Fig. 10—Photomicrographs of Specimens of Steel whose Ac_1 is shown in Figs. 2 and 6—Fig. 10a—Showing a Segregated Condition.—Fig. 10b—Specimen Quenched from 724 Degrees Cent. Fig. 10c—Specimen Quenched from 730 Degrees Cent. Fig. 10d—Specimen Quenched from 734 Degrees Cent. These Photomicrographs Show Progressive Solution of Pearlite within the Ac_1 Interval. Specimens etched in 1 Per Cent Alcoholic Nitric Acid. Magnification 350x. (Initial Magnification 600x.)

of the steel of runs 3-5, after normalizing and after annealing, did not affect Ac_1, nor did the presence of lamellar pearlite in No. 3, and completely spheroidized or granular cementite in No. 5.

A hint of a possible explanation may lie in the amount or nature of the non-metallic inclusions, since in the author's experience steels made in the crucible or the acid open-hearth fur-

nace show a smaller interval than do those made in the basic open-hearth or Bessemer furnaces. The latter, of course, contain more inclusions than the former.

The steel used in runs 6 and 7 was quenched from differ-

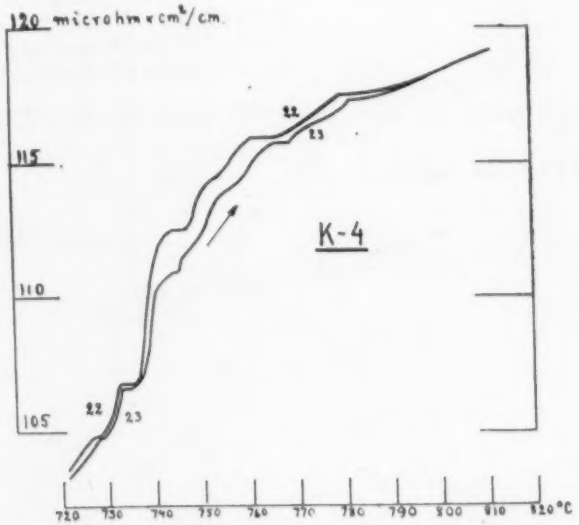

Fig. 11—Pearlite Interval of Same Steel Shown in Fig. 5 after Remelting and Adding Silicon. Composition now 0.37 Per Cent Carbon, 0.05 Per Cent Manganese and 0.42 Per Cent Silicon.

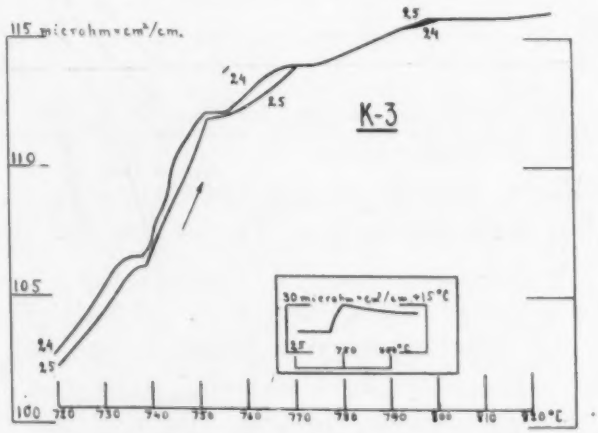

Fig. 12—Pearlite Interval of Steel of 0.30 Per Cent Carbon, 0.02 Per Cent Manganese and 1.21 Per Cent Silicon. Inset—Resistance at 15 Degrees Cent. after Quenching from Temperature Shown.

ent temperatures and the resistance of the quenched specimens determined at 15 degrees Cent. The small Ac_1 interval is confirmed by these tests.

Ac_1 in Steels Containing Manganese

Runs 8-21 (Table I) were made on steels of various carbon

contents in which the manganese varied from 0.35 to 1.62 per cent. The more completely diffused specimens of each steel gave the following intervals in Ac_1:

Per Cent Manganese	Ac_1
0.35	727 — 733 = 6 degrees
0.47	727 — 735 = 8 degrees
1.07	720 — 733 = 13 degrees
1.62	708 — 722 = 14 degrees

Thus the beginning of the interval falls as manganese increases,

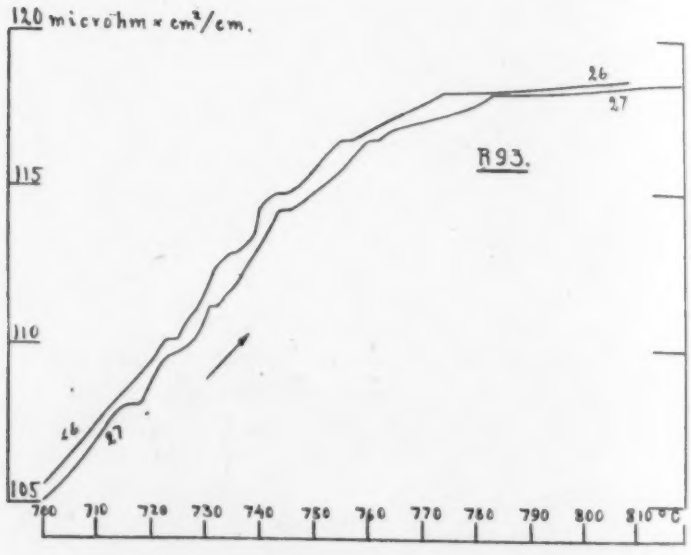

Fig. 13—Pearlite Interval and Unexplained Points in Steel of 0.48 Per Cent Carbon, 0.76 Per Cent Manganese and 1.86 Per Cent Silicon.

the range widens, and the end is approximately constant up to 1 per cent but falls thereafter. The curves for these steels are shown in Figs. 6-9.

The 0.47 per cent manganese steel (steel P-60) shows a 12 or 13 degree Ac_1 interval when segregated, and one of 8 degrees when diffused. The segregated material, after run 10 (see Table I) had the structure shown in Fig. 10a and Ac_1 starts at 722 degrees Cent., continuing to 735 degrees Cent.

By quenching in water after 10 minutes at 724 degrees Cent., just above the beginning of Ac_1, it is shown (Fig. 10b) that the pearlite has started to dissolve. The dissolved carbon comes out as granular cementite on quenching so that both lamellar pearlite and granular cementite appear. On quenching from 730 degrees Cent. (1346 degrees Fahr.), i. e., somewhat above the middle of the range, the pearlite is still further dissolved (Fig. 10c). On

quenching from 734 degrees Cent. (1353 degrees Fahr.), i. e., almost at the end of the range, the pearlite is nearly gone and martensite and troostite appear on quenching, as shown in Fig. 10d.

On all four steels heat treatment that would be expected to

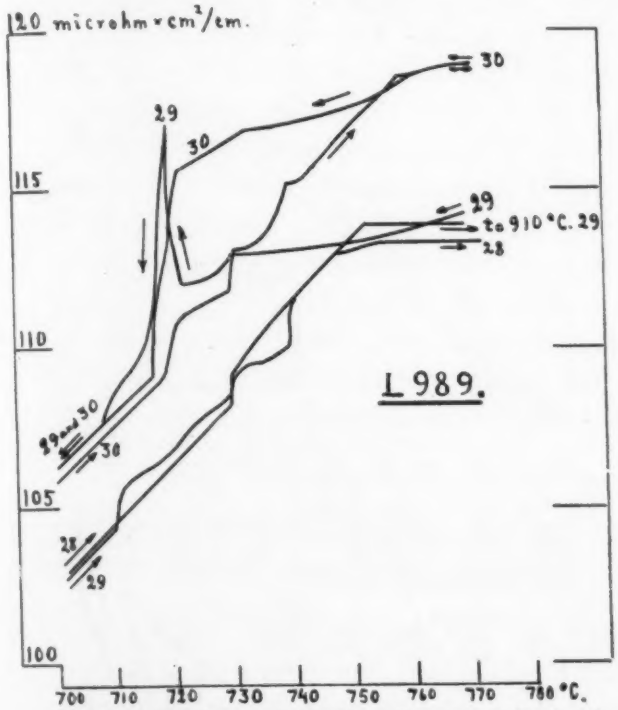

Fig. 14—Heating and Cooling Curves of Steel of 1.05 Per Cent Carbon, 0.26 Per Cent Manganese and 1.39 Per Cent Silicon.

diffuse the manganese and promote homogeneity, such as long annealing and slow cooling, or quenching from a high temperature followed by rapid tempering, produced a smaller Ac_1 range than did a treatment such as normalizing or relatively rapid cooling (but not a quenching) through the critical ranges, which would tend to promote segregation.

Ac_1 in Steels Containing Silicon

Runs 11-14, Table I, were made on a steel containing 0.33 per cent silicon, but the effect of silicon was not evident in the presence of the 1.07 per cent manganese contained in that steel.

Runs 22 and 23 (Table I and Fig. 11), made on a steel, K-4, with 0.42 per cent silicon and only 0.05 per cent manganese, however, show the same Ac_1 interval, 729-733 degrees Cent., as was shown in runs 6 and 7 on this same steel (W) before re-

melting and adding silicon, and a second and higher Ac_1 interval, which is obviously due to the silicon, and which is practically unchanged, whether the steel is segregated or diffused.

In another steel (K-3) with only 0.02 per cent manganese, but with 1.21 per cent silicon, there is only one marked Ac_1 interval (Fig. 12), although there is an inflection in the curves at

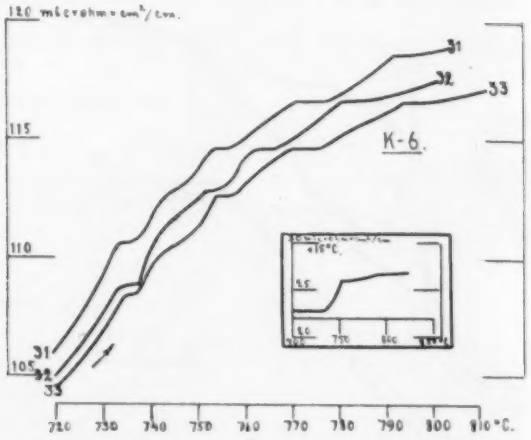

Fig. 15—Pearlite Interval in Steel of 0.23 Per Cent Carbon, 0.01 Per Cent Manganese, 0.035 Per Cent Silicon and 0.99 Per Cent Phosphorus. Inset —Resistance at 15 Degrees Cent. after Quenching from Temperatures Shown.

about the usual 733-735 degrees Cent. temperature, extending for 2 to 4 degrees Cent. before the strong Ac_1 begins.

The strong Ac_1 extends over 13 or 14 degrees Cent. instead of the 8 or 9 degrees Cent. of the 0.42 per cent silicon steel, but, as was the case with that steel, was not altered by normalizing or annealing.

Runs 26 and 27 on a silicon-manganese steel R-93 (Fig. 13), with 0.76 per cent manganese and 1.86 per cent silicon, show the doubling of the interval. The lower, or manganese, interval is shortened by diffusing the material, while the upper, or silicon, interval is scarcely affected. There also appears another point at 755-757 degrees Cent. in the diffused sample and at 760-762 degrees Cent. in the segregated one, for which no adequate explanation can be given by the author, unless it pertains to the phenomenon mentioned in the next paragraphs.

Runs 28-30 were made on a steel L-989, containing 1.05 per cent carbon, 0.26 per cent manganese and 1.39 per cent silicon. With the combination of high carbon and high silicon, erratic results may be obtained, possibly due to graphitization. Fig. 14.

in which are included two cooling curves, shows erratic results. The peak in the cooling curve No. 29 from 910 degrees Cent. was obtained on four other tests with different samples, but in other cases, in which conditions were thought to be duplicated, it did not appear. In heating after this peak had occurred, two extra points appeared at 740 and 759 degrees Cent. These anomalies and the wide differences in resistance and shape of curve noted in successive runs, instead of the small differences and practical parallelism of the curves for successive runs in the steels heretofore described might be due to precipitation of graphite, the explanation that naturally comes to mind for a steel containing high carbon and high silicon.

Attempts to produce graphitization and to follow them microscopically were made. It was possible to produce some graphitization, but the data were insufficient to prove any connection between graphitization and the erratic points, and indeed, indicate to the author that graphitization cannot be wholly responsible.

Ac_1 in Steel Containing Phosphorus

Runs 31-33 (Table I) were made on a steel with 0.99 per cent phosphorus practically free from manganese and silicon. The Ac_1 interval was raised and was unaffected by normalizing and annealing (Fig. 15). The behavior of phosphorus is quite similar to that of silicon.

Acknowledgments

Acknowledgment is due my colleagues at the Bureau of Standards, Washington, H. W. Gillett, L. Jordan and S. Epstein, for kindly assistance in preparing this report in English and for constructive criticisms. Thanks are due to Erland Bergh, director of the Kloster Steel and Iron Works, Sweden, to Prof. Carl Benedicks and Prof. Arvid Johansson of Stockholm, and to Prof. H. Hanemann of Berlin for their interest and help in this work and to my assistant, Albin Larsson, Langshyttan, for his efficient aid in the five years of work on the subject of this report. The experimental work was done at the Kloster Steel and Iron Works, Langshyttan, Sweden.

OBSERVATIONS ON TEMPERATURE DISTRIBUTION IN STEEL BODIES COOLED IN AIR

By E. J. Janitzky

Abstract

In this article the writer presents a method of approximating temperature drops at any instant and at any distance from center in steel bodies cooled in air to ordinary atmospheric temperature, when total time to reach coolant temperature and exponent of center curve equation are given.

THE writer developed and published in an article entitled *Characteristics of Air-Cooling Curves*[1] an equation which enables one to approximate temperature drops at any instant when cooling steel bodies to ordinary atmospheric temperature of about 80 degrees Fahr.

This formula, which was developed only for a specific case, in the generalized form will read:

$$t_1^\circ = \frac{T^\circ}{\left(\frac{T^\circ}{t^\circ} - 1\right)\left(\frac{t_1}{t}\right)^n + 1} \qquad (1)$$

T° = head temperature;
t_1° = temperature corresponding to the instant t_1;
t° = temperature corresponding to the instant t;
(t° must be lower than t_1° and may be coolant temperature, in which case t denotes the total time required to reach coolant temperature).
n = an exponent which depends on the head temperature, the character of the coolant and the location from center.

It will be noted that the exponent "n" is the salient point and can be obtained from the above formula.

$$n = \frac{\log(T^\circ - t_1^\circ)t^\circ - \log(T^\circ - t^\circ)t_1^\circ}{\log t_1 - \log t} \qquad (2)$$

Having "n," one is able to calculate the time required to reach the coolant temperature, which in air-cooling is approximately 80 degrees Fahr., according to the equation:

$$t = t_1 \sqrt[n]{\frac{T^\circ - 80}{\left(\frac{T^\circ}{t_1^\circ} - 1\right).80}} \qquad (3)$$

Obviously, by having "n" and "t," temperature drops at any instant can be approximated.

[1] Transactions, A. S. S. T., December, 1922, pp. 335-338.

The author of this paper, E. J. Janitzky, is metallurgical engineer with the Illinois Steel Co., South Chicago, Illinois.

The writer obtained through the courtesy of J. F. Harper, research engineer, Allis-Chalmers Co., Milwaukee, Wisconsin, time-temperature observations on air-cooled 12-inch cubes—one from 1120 degrees Fahr. and another from 1620 degrees Fahr., taken centrally, midway and three-quarters from the center—and in this article it is aimed to find the relation of temperature distribution at the surface and any distance between center and surface at the same instant when data for the center equation are given, namely, "n" and "t."

In scrutinizing the experimental observation (Fig. 1) obtained by cooling a 12-inch cube from a temperature below the critical point (1120 degrees Fahr.), it appears that the temperature drop at any instant of the surface is satisfied by taking the reciprocal value of the center equation exponent.

This assumption seems to be fortified by the following procedure:

In applying the equation for temperature drop at any instant to temperature distribution at any distance between center and surface at the same instant, the equation will read:

$$D^\circ = \frac{C^\circ}{\left(\frac{C^\circ}{S^\circ} - 1\right) d^n + 1}$$

D° = temperature at any distance between center and surface;
C° = temperature at center;
S° = temperature at surface;
n = exponent which appears to be "3";
d = distance from center;

and the so-obtained data coincides closely with the experimental observations, as seen later in the sample calculation.

In cooling from above the critical point (see Fig. 2) one has to deal with two component parts—namely, from the head temperature to the critical point and from the critical point to coolant temperature. Therefore, two center equation exponents have to be given and also the corresponding time intervals.

The exponent of the surface equation for temperature drops from the head temperature at any instant appears to be the reciprocal of the square root of the center equation exponent above the critical point to the instant when the center passes the critical point. From that point down to coolant temperature the surface equation exponent is the same as that of center equation for the

same time interval. The temperature distribution between center and surface is calculated similar to the preceding case.

The following is J. F. Harper's description of the procedure in taking the time-temperature graphs:

Analysis of the 12-inch cube—

	per cent
Carbon	0.27
Manganese	0.53
Phosphorus	0.017
Sulphur	0.031
Silicon	0.139

"The heating of the block was in an oil-fired semi-muffle furnace. The block was supported on angle iron supports which, in turn, rested on brick piers in the furnace.

"The block was removed from the furnace with an electric

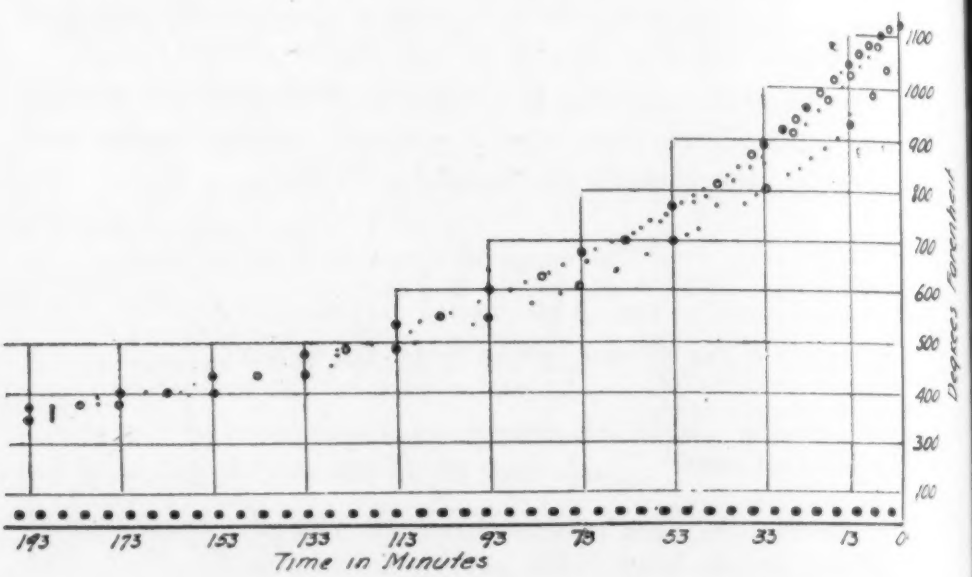

Fig. 1—Time-Temperature Curves Taken Centrally, Midway, and Three-Quarters Distance from Center of a 12-Inch Cube Cooled in Air from 1120 Degrees Fahrenheit.

truck. The elapsed time from the furnace to the quenching tank or rack was 27 seconds.

"For air-cooling the block was supported on the angle iron base on two supports 30 inches from the floor. Air temperature was 70 degrees Fahr.

"The temperature recorder was a Leeds and Northrup Potentiometer, 16-point recorder. Iron-constantan couples with iron protection pipes were welded into the block. The system was checked for accuracy with a laboratory Leeds and Northrup Poten-

tiometer, indicator and a plantinum—platinum–rhodium thermocouple, which had been checked by the Bureau of Standards.''

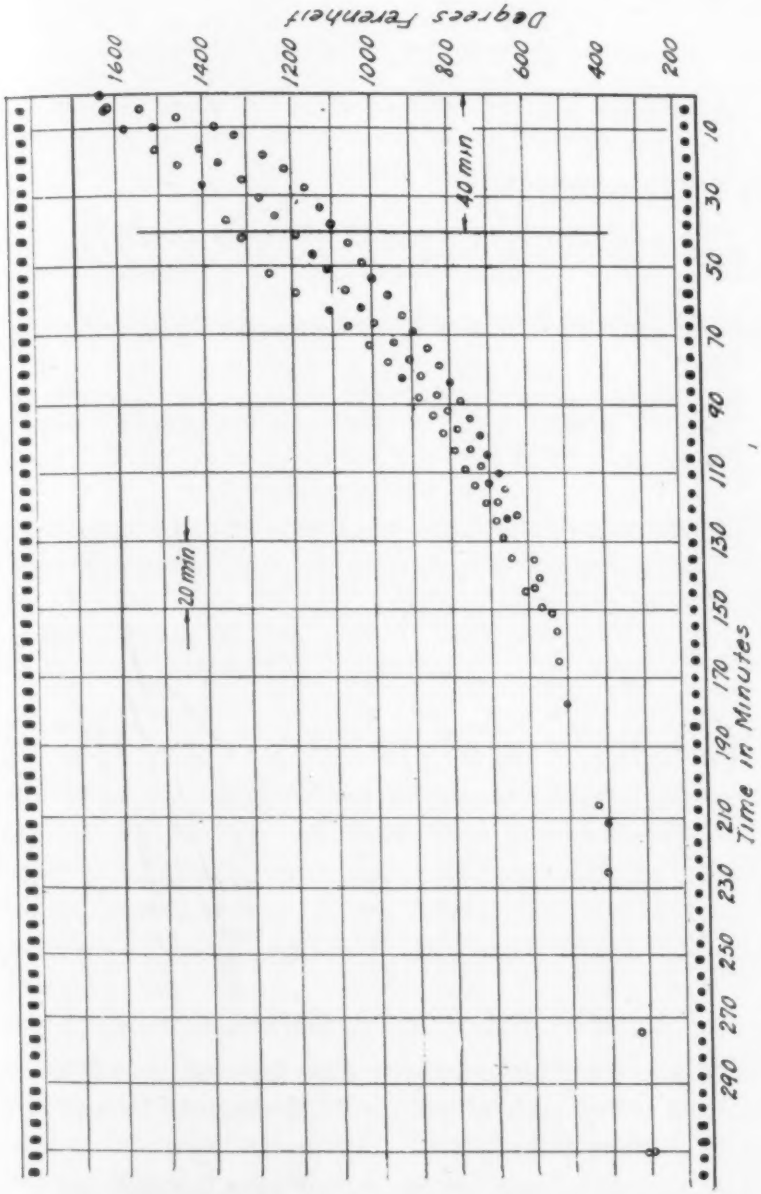

Fig. 2—Time-Temperature Curves Taken Centrally, Midway, and Three-Quarters Distance from Center of a 12-Inch Cube Cooled in Air from 1620 Degrees Fahrenheit.

Calculations

Temperature drops calculated at center, surface and distances between center and surface, when center curve exponent and total time to reach coolant temperature are given.

Data as given for center curve of a 12-inch steel cube, air-cooled from 1120 degrees Fahr. to approximately 80 degrees Fahr. (See Fig. 1.)

Temperature Degrees Fahr.	Time in Minutes
$T^\circ = 1120$	0
$t_1^\circ = 890$	33
$t^\circ = 300$	253

Center curve exponent:

$$n = \frac{\log(T^\circ - t_1^\circ)\, t^\circ - \log(T^\circ - t^\circ)\, t_1^\circ}{\log t_1 - \log t} = \frac{1.02435}{0.88465} = 1.158$$

Total time required to reach atmospheric temperature of 80 degrees Fahr.:

$$t = t_1 \sqrt[n]{\frac{T^\circ - 80}{\left(\frac{T^\circ}{t_1^\circ} - 1\right).80}} = 973 \text{ minutes}$$

Temperature drops from head temperature at center and surface and temperature distribution at any distance between center and surface at the same instant:

	Center T°		Midway C°		¾ from Center C°		Surface T°
Time in Minutes	$\left(\frac{T^\circ}{80} - 1\right)\left(\frac{t_1}{t}\right)^n + 1$		$\left(\frac{C^\circ}{S^\circ} - 1\right).5^2 + 1$		$\left(\frac{C^\circ}{S^\circ} - 1\right).75^3 + 1$		$\left(\frac{T^\circ}{80} - 1\right)\left(\frac{t_1}{t}\right)^{\frac{1}{n}} + 1$
	Calc.	Act.	Calc.	Act.	Calc.	Act.	Calc.
13	1030	1040	1004	1020	947	930	854
33	890	890	852	870	775	800	660
53	774	770	735	750	658	700	545
73	680	680	644	660	571	600	469
93	603	600	570	580	505	540	411
113	541	540	516	510	455	480	370
133	487	480	465	470	410	440	336
193	374	370	355	370	320	350	266

Calculation of temperature distribution in air-cooling from temperature above critical point (1320 degrees Fahr.) to approximately 80 degrees Fahr.

Data as given from center curve of a 12-inch steel cube air-cooled from 1620 degrees Fahr. (see Fig. 2).

Above Critical Point		Below Critical Point	
Temperature Degree Fahr.	Time in Minutes	Temperature Degree Fahr.	Time in Minutes
$T^\circ = 1620$	0	$T^\circ = 1320$	0
$t_1^\circ = 1520$	15	$t_1^\circ = 1020$	30
$t^\circ = 1320$	40	$t^\circ = 300$	260

Center curve exponent n = 1.26
Time elapsed to passing critical point .....40 Min.

Center curve exponent n = 1.133
Time elapsed from critical point to coolant temperature .....992 minutes

Total time elapsed in cooling from head temperature to coolant temperature.. 992 + 40 = 1032 minutes.

Temperature drops of center and surface and temperature distribution between center and surface at any distance and at the same instant:

Above Critical Point

Time in Minutes	Center 1620° $\left(\frac{1620^\circ}{1320^\circ}-1\right)\left(\frac{t_1}{40}\right)^{1.26}+1$		Midway C° $\left(\frac{C^\circ}{S^\circ}-1\right)0.5^3+1$		¾ from Center C° $\left(\frac{C^\circ}{S^\circ}-1\right)0.75^3+1$		Surface 1620° $\left(\frac{1620}{80}-1\right)\frac{t_1}{1032}^{\frac{1}{\sqrt{1.26}}}+1$
	Calc.	Act.	Calc.	Act.	Calc.	Act.	Calc.
10	1560	1570	1510	1500	1405	1390	1235
20	1480	1450	1400	1360	1250	1220	1030
40	1320	1320	1225	1220	1030	1080	785

Below Critical Point

	1320 $\left(\frac{1320}{80}-1\right)\left(\frac{t_1}{992}\right)^{1.133}+1$		C° $\left(\frac{C^\circ}{S^\circ}-1\right)0.5^3+1$		C° $\left(\frac{C^\circ}{S^\circ}-1\right)0.75^3+1$		785 $\left(\frac{785}{80}-1\right)\left(\frac{t_1}{992}\right)^{1.133}+1$
	Calc.	Act.	Calc.	Act.	Calc.	Act.	Calc.
70	1020	1020	960	960	850	880	670
130	655	665	630	640	575	600	495

Conclusions

Considering the experimental errors, the calculated results approximate the values read off from the time-temperature graphs.

As to the time required to reach coolant temperature of larger or smaller sections than the 12-inch cube in question, it may be said that the time of cooling will vary inversely to surface per cubic unit exposed.

Having determined experimentally center cooling curves from different temperatures and derived from them mathematically the center curve exponent and total time required to reach coolant temperature, the so-obtained two factors will enable one to approximate the surface cooling curve and the temperature distribution in cooling steel bodies.

As to other coolants than air, the writer believes they can be treated identically when "n" and "t" are given.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE MANUFACTURE OF IRON AND STEEL—PART IV

By F. T. Sisco

Abstract

In the present installment, the last of the series, three widely diversified products are discussed. These three, wrought iron, malleable iron and semi-steel, unimportant in their relation to the whole iron and steel industry, are important in themselves in that they have characteristic properties that fit them especially for certain products. Wrought iron is a hot-rolled product, malleable iron and semi-steel are used in the forms of castings. The manufacture, properties, and uses of each are discussed in the present installment.

IN the series of articles on the manufacture of iron and steel three products have not been discussed. Wrought iron, malleable iron and semi-steel, although widely diversified in nature and uses, may be conveniently grouped together and discussed in the present installment. These three products, made in relatively small tonnage each year, are unimportant when the whole output of the iron and steel industry is considered. They are, however, very important in themselves in that they are cast or fabricated into finished products with characteristic properties and uses: products which cannot be conveniently or economically fabricated or cast of any other ferrous material. This statement holds true, of course, only in a sense, as there have been many substitutions. For example, mild steel has been substituted for wrought iron, but these substitutions have, in general, never resulted in as satisfactory a product.

Malleable iron and semi-steel are used only in the form of castings, wrought iron is nearly always used as the hot or cold-

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worked material. In England wrought iron is used as a raw material in the manufacture of steel by the crucible process.

Wrought Iron

The manufacture of wrought iron is one of the oldest ferrometallurgical processes. Essentially the process has undergone no change. The manufacture of wrought iron is known as "puddling," and the finished product is known as "puddled bar or muck bar." Puddling is practically the only melting and refining process in which hand labor has not been replaced by machinery and labor saving devices. It is true that mechanical puddling furnaces have been devised and in isolated instances are in use. However, mechanical puddling has not become successful to the point where the puddler is no longer necessary.

The Puddling Furnace—The puddling furnace is a reverberatory furnace with a horizontal, or nearly horizontal, hearth. It is constructed of steel plates lined with firebrick and is usually coal-fired. The hearth of the furnace is lined or "fettled" with iron oxide. The fettle may be roll scale, a pure iron ore, puddle slag, or a mixture of these iron oxides. After the fettle is spread on the hearth the furnace is heated until the oxide fuses or sinters. After the bottom is set the iron oxide is worked up onto the sides to form a shallow, saucer-shaped hearth.

Puddling furnaces range from 500 to 1500 pounds in size; about 1000 pounds is common. The capacity is limited by the ability of the puddler to handle the charge. The pig iron used is the grade known as forge iron and commonly contains about 1.00 per cent silicon, about 0.75 per cent manganese and less than 0.10 per cent sulphur. The percentage of phosphorus varies according to the requirements of the product; for high grade muck bar containing less than 0.025 per cent phosphorus to be made into crucible steel it is usually 0.10 per cent or below. The usual permissible amount of phosphorus varies between 0.060 and 0.250 per cent. The amount in the iron may, therefore, range from 0.250 to 1.00 per cent.

Melting and Refining—The pig iron is charged onto the hearth and melted as rapidly as possible. Manganese and silicon are almost completely eliminated by the time melting is complete. By keeping the temperature as low as possible the phosphorus is next oxidized. This is followed by the oxidation of the carbon. As the

percentage of carbon becomes progressively less the melting point of the bath raises until, finally, when the residual carbon is 0.25 per cent or below, the heat of the furnace is no longer sufficient to keep the bath molten. The molten metal starts to get mushy or "comes to nature." As soon as this occurs the puddler opens the furnace and by means of a long iron bar gathers the pasty metal into balls of about 150 pounds each. As rapidly as possible these are removed from the furnace and taken to the squeezer.

The squeezer is a circular, corrugated cylinder, which revolves a little off center about a smaller stationary cylinder, also corrugated (Fig. 1). The white-hot dripping ball is placed in the squeezer, which, in rotating, presses it into the form of a cylindri-

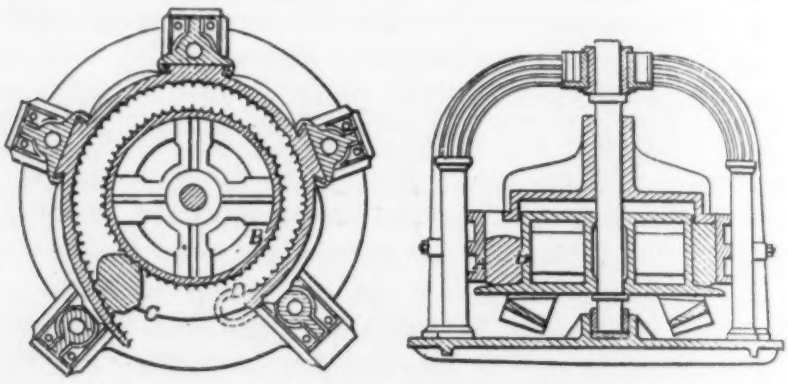


Fig. 1—Squeezer for Puddled Iron.[1]

cal bloom 15 to 20 inches in diamter and 24 to 30 inches long. In squeezing, most of the slag which is liquid is forced out of the metal. The cylindrical bloom is now ready for rolling.

Chemistry of the Puddling Process—Puddling is an oxidizing process, in which the impurities are removed through the agency of iron oxide and a strongly basic slag.

As soon as the pig iron is melted, about 90 per cent of the silicon has been oxidized and has passed into the slag. In another five minutes nearly all the manganese has also been eliminated. The ractions by which these two elements are oxidized

$$(1)\quad 2FeO + Si \rightarrow 2Fe + SiO_2$$
$$(2)\quad FeO + Mn \rightarrow Fe + MnO$$

are the same as in any oxidizing melting process.[2] Reactions 1 and 2 will be basically the same whether the iron oxide is present, as FeO, Fe_3O_4, or Fe_2O_3, or as mixtures of these oxides. The oxide

[1]Bradley Stoughton, "Metallurgy of Iron and Steel," page 74, 1923.

[2]See first installment of this series, TRANSACTIONS, August, 1925, pages 217 and 228.

comes from iron ore or roll scale added to the furnace or eroded from the hearth of the furnace.

As soon as the pig iron is all melted more iron ore is added and the bath is cooled by dampering the furnace. The silicon and manganese have been oxidized by this time, so a comparatively low temperature is desired to speed up the oxidation of the phosphorus (reactions 3a and 3b), which takes place most rapidly at a low temperature:

$$(3a)\quad 5FeO + 2P \rightarrow 5Fe + P_2O_5$$
$$(3b)\quad 3FeO + P_2O_5 \rightarrow (FeO)_3(P_2O_5)$$

The phosphorus passes into the slag, where it is held as ferrous phosphate, stable as long as the slag is strongly basic.

After the phosphorus has been oxidized the temperature is increased and the oxidation of the carbon becomes rapid (reaction 4a and 4b):

$$(4a)\quad FeO + C \rightarrow Fe + CO$$
$$(4b)\quad CO + FeO \rightarrow Fe + CO_2$$

The rapid evolution of gas produces a violent boil, during which about half of the slag is ejected out of the slag hole.

During the boil it is necessary that the percentage of FeO in the slag be high so reaction 4b will take place as indicated. As carbon monoxide, CO is an active reducing agent. It will reduce the phosphoric acid (P_2O_5) in the slag to phosphorus unless the ferrous oxide is in great excess.

Sulphur removal takes place after the metal is molten, usually about the same time that the phosphorus is being oxidized. The reactions cannot be stated with certainty, probably the element is oxidized to sulphur dioxide, which passes off as a gas. Some may be removed as manganese sulphide.

The puddling furnace slag is composed of ferrous silicate, a little manganese silicate, ferrous phosphate, a small amount of ferric oxide and free ferrous oxide.

Rolling the Puddling Iron—The cylindrical blooms from the squeezer are rolled to flat sections about ¾ x 4 inches in size and cut into lengths of 2 to 3 feet. These lengths are piled in layers, each layer being at right angles to the one beneath it, and tied with wires. The bundle is then heated to a welding heat and again rolled down to flat bars. The product is known as single refined iron. If the material is again put through the cutting, piling and rolling process it becomes double refined iron.

An inferior grade of wrought iron is made by cutting, piling

and rolling wrought iron scrap. Often scrap is mixed with puddled bar and rerolled.

When the ball of pasty iron is removed from the furnace a large amount of slag is entrapped in the metal. Most of this is forced out by the squeezer. More is removed in rolling, so that the finished muck bar contains about 1 per cent entrapped slag. This slag is elongated by the rolling process into fibers, whose major axes are in the direction of rolling, Figs. 2 and 3. Piling the wrought iron bars with their major axes at right angles to each other and rerolling serves to produce a finished material, in which the slag fibers run both longitudinally and transversely.

Properties and Uses of Wrought Iron—Wrought iron is, in general, a very pure grade of iron, containing as its chief impurity about 1 per cent slag. Typical analyses of wrought iron are as follows:

	For Steel Making Per Cent	Double Refined Iron Per Cent
Carbon	0.05 –0.15	0.05 –0.20
Silicon	0.10 –0.15	.....
Manganese	0.05 –0.10	0.05 –0.20
Sulphur	0.015–0.020	0.020–0.060
Phophorus	0.015–0.030	0.050–0.150

In physical properties wrought iron has a tensile strength of 40,000 to 55,000 pounds per square inch, an elastic limit of 25,000 to 30,000 pounds per square inch, and an elongation of 15 to 25 per cent in 2 inches and a reduction of area of about 45 per cent. In general, a double refined iron has better properties than a single refined iron. Wrought iron is very ductile and may be severely deformed cold without indication of failure. Its resistance to fatigue and alternating bend tests is excellent.

Wrought iron is quite resistant to oxidation. Its ability to withstand corrosion is claimed by many to be superior to steel. This point, however, has been often disputed. A remarkable example of its oxidation resisting properties is the iron pillar of Delhi, India, which has stood for 1600 years without noticeable corrosion. In a recent investigation of this pillar Sir Robert Hadfield found the structure to be almost wholly pure ferrite, with practically no slag. Consequently it cannot be called a true wrought iron as we know it today, although no doubt it was produced in some manner similar to puddling.

Wrought iron is used chiefly for engine bolts, stay bolts, draw

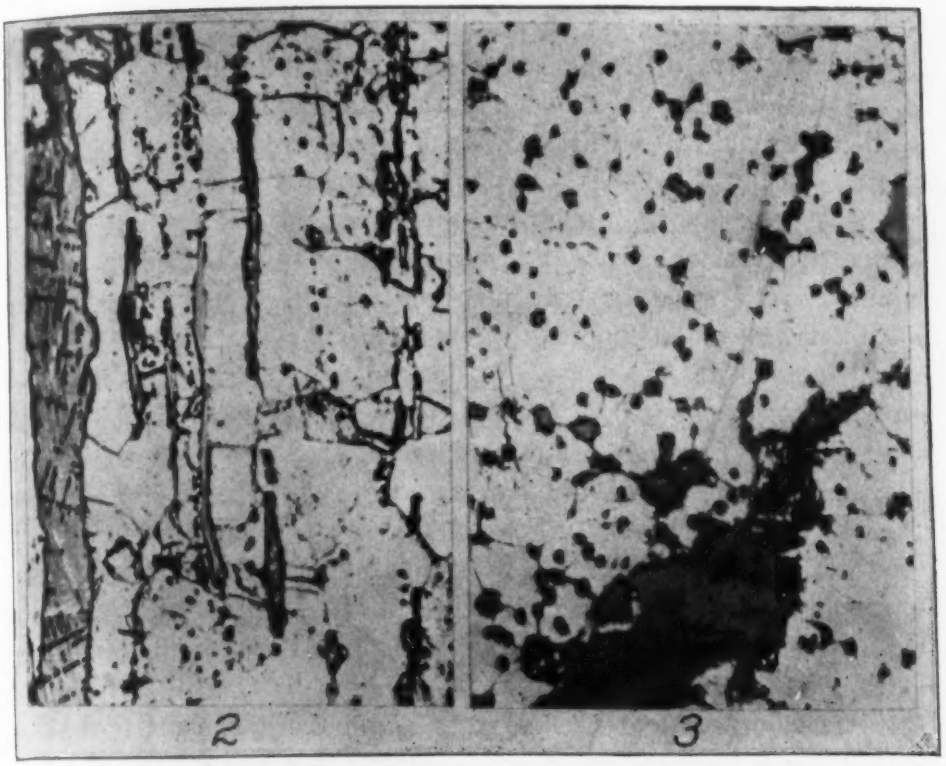


Fig. 2—Wrought Iron, Longitudinal Section, Etched, 100 X. Fig. 3—Wrought Iron, Transverse Section, Etched, 100 X. (From Metallurgical Files, McCook Field.)

bars of locomotives, pipes, chains, etc. The quality of wrought iron cannot always be predicted by its chemical composition or physical properties.

Low carbon steels made by the Bessemer and open-hearth processes have supplanted wrought iron for many purposes; but the complete extinction of the puddling process, which was freely predicted when the Bessemer and open-hearth were perfected, has never taken place.

Malleable Iron

In the manufacture of malleable iron castings, pig iron and scrap are melted in an air furnace or cupola and poured into a sand mold. The iron casting, which, after solidification and cooling, is hard, brittle and weak, is made soft and ductile by an annealing process. Before annealing, all of the carbon in the iron is in the form of cementite Fe_3C. By regulating the temperature and time of annealing practically all of this constituent is dissociated into iron and free carbon. The carbon in the finished casting occurs in the form of rounded areas of temper carbon.

This temper carbon is chemically identical with the graphite of gray cast iron, differing only in geometric form, Figs. 4 and 6. Due to this difference in form the malleable casting is stronger and better able to withstand shock than the gray iron casting, in which the graphite occurs as thin irregularly shaped flakes.

Composition of the Iron Used for Malleable Castings—The composition of the iron and scrap used in pouring castings to be malleableized must be carefully controlled. Next to the carbon, silicon is the most important element, as it affects the dissociation of the cementite. It is usually desired to have the silicon content in the charge about 0.60 to 0.80 per cent. A much higher silicon content may promote graphitization of the carbon in the solidification and cooling of the casting, which would defeat, in part, the object of the annealing process. A silicon content of 0.40 to 0.50 per cent causes trouble in annealing. In this case the silicon is too low for complete dissociation of the iron carbide. In addition the silicon would be so low that some iron might oxidize, resulting in an unsound casting.

A carbon content of 2.25 to 2.50 per cent is usually desired; with a higher percentage it is impossible to prevent some graphitization from occurring before annealing. The formation of graphite is also dependent upon the rate of cooling. Thus, in order to have a casting in which all of the carbon is combined before annealing, and all in the form of temper carbon after annealing, it is necessary to take the three factors, namely, size of casting, total carbon, and silicon content, into consideration. In the case of castings of heavy section the carbon or silicon percentage must be lower than usual to prevent premature graphitization. In castings of one inch cross-section the silicon content may be as low as 0.40 per cent. On the other hand, castings of very thin sections may contain 0.90 to 1.00 per cent of the element.

Manganese is usually low, about 0.50 per cent. It is necessary to have enough present to insure that all of the sulphur will be in the form of manganese sulphide. Manganese is thought to prevent the oxidation of the iron and to prevent scaling in the annealing; too much, however, makes the casting difficult to machine. About 0.60 to 0.70 per cent is the upper limit for the element.

The percentage of sulphur is usually low, below 0.06 per cent in the best practice. Some authorities claim that the element

increases 0.005 to 0.030 per cent in the annealing, due, probably, to absorption of sulphur from the furnace gases. It has lately been shown,[3] however, that sulphur is lost in annealing. This loss is due to volatilization of a portion of the element which exists as some compound other than manganese or iron sulphide.

Phosphorus in large amounts makes the iron more fluid. When the percentage is above 0.250 brittleness is increased, lessening the ability of the casting to withstand shock.

Furnaces for Melting the Iron—Iron for malleable castings is melted in either an air furnace or cupola. The charge is usually made up of about 80 per cent pig iron and 20 per cent scrap. The scrap will consist of defective castings, gates, risers and the like. Some steel scrap is always used to reduce the percentage of total carbon.

Melting in a cupola is similar to melting for gray iron castings, described in the previous installment. The coke consumption will be considerably greater because of the higher temperature necessary, due to the lower total carbon content of the charge. Melting in a cupola has the advantage of lower cost; it is also possible to secure higher and more uniform temperature. The principal disadvantage is that the metal is likely to be heterogeneous in composition. In cupola melting no great amount of molten metal is collected in the hearth at one time. Successive meltings during the run of the cupola may change radically in composition. This disadvantage has led to cupola-melted castings being prohibited by the American Society for Testing Materials.

The air furnace is a reverberatory furnace, with a cup-shaped horizontal hearth, lined with silica refractories. Most air furnaces are coal-fired, modern installations using powdered coal. The fire box is at one end of the furnace; the hot gases are drawn through the melting chamber, over the hearth to the stack at the other end. Many air furnaces use natural draft only. It is common, however, to admit the air under a pressure of 4 to 12 ounces, thus making a very tall stack unnecessary.

The capacity of the furnace varies from 5 to 20 tons; the average is 10 to 15 tons. The melting time is approximately 15 minutes per ton and the fuel used averages about 1000 pounds of coal per ton of metal.

Melting and Pouring—The charge is packed solidly on the

[3]Crowe, *Chemical and Metallurgical Engineering*, Vol. 25, No. 6, 1921, page 247.

hearth. The pig iron and scrap castings melt first; this is followed by the steel. As the temperature of the furnace does not exceed 2400 to 2600 degrees Fahr., probably the steel does not melt; rather it dissolves in melted iron. Some iron is oxidized in melting. This will react with some of the silicon and manganese in the charge, and with the sand and dirt on the iron and scrap and with the lining to form a silicate slag, acid in character. At intervals this slag is skimmed off of the metal.

The progress of the heat is followed by taking a spoonful of metal at frequent intervals and pouring it into a small mold. When this test piece is cold it is fractured and from the appearance of the fracture the condition, composition and temperature of the metal are judged. When the fracture is practically free from dark spots of graphite, the metal is tapped into a ladle and the casting poured.

Pouring is ordinarily done by the molders either from hand ladles or from "bull" ladles carried by two men. In a few shops which specialize in heavy work, wheeled ladles, known as "sulkies," are used. This is comparatively rare, as most malleable castings are small in section.

Digging out and cleaning involve no special difficulties. The casting, as poured, is exceedingly brittle; gates and risers are easily broken. In fact, care must be taken to avoid breaking the casting. After the castings are cleaned they are inspected. They are then ready for annealing.

Annealing the Casting—The castings are packed in cast iron or steel annealing boxes, known as pots. It is customary, but by no means a universal, practice to pack the castings in iron oxide, such as iron ore or scale, or in ground air furnace slag, quartz sand, or the like. The pots are covered tightly and placed in an annealing furnace.

The annealing cycle is five to seven days, but this may vary widely, depending upon the size of the furnace, the size of the castings and other factors.

The furnace is heated slowly to the prescribed temperature and held at this point for 40 to 70 hours. Cooling is slow, about 10 degrees per hour. Annealing temperatures range from 1500 to 1800 degrees Fahr. In the best practice the castings are held at 1600 to 1650 degrees Fahr. for 40 to 50 hours. The higher temperatures speed up the graphitization of the cementite, but

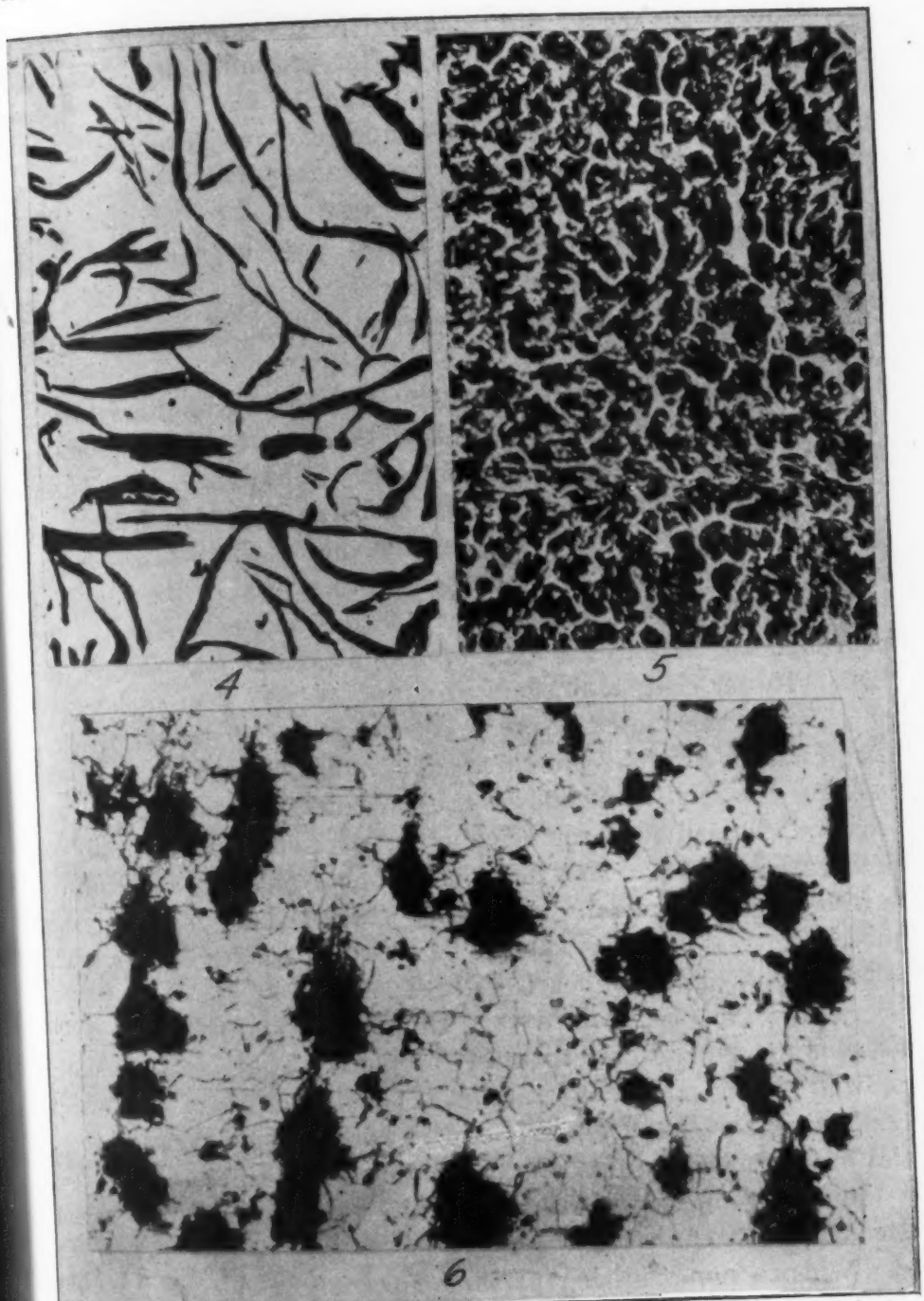


Fig. 4—Gray Cast Iron, Not Etched, 100 X. Fig. 5—White Iron, Before Graphitization, Etched, 100 X. Fig. 6—Malleable Cast Iron, Etched, 100 X.

introduce several factors which are of disadvantage, namely, crystal growth of the ferrite grains, sintering of the packing materials, early destruction of the refractories, etc.

Microstructure of Malleable Iron—Figs. 5 and 6[4] show the structure of the iron before and after graphitization. In Fig. 5 the carbon is all present as iron carbide, Fe_3C. In Fig. 6 the carbon occurs as rounded areas of temper carbon (graphite). Fig. 6 may be compared with Fig. 4, the normal structure of gray cast iron.

The mechanism of graphitization may be expressed by the reaction

$$Fe_3C \rightarrow 3Fe + C$$

which represents the transition from metastable to stable equilibrium.

It has been noted that temper carbon and graphite are chemically identical. Temper carbon is crystalline, but in such a finely divided state as to appear amorphous. Schwartz has aptly illustrated this by comparing temper carbon to powdered sugar and graphite to rock candy. The reaction noted above proceeds from left to right, rapidly at first, then more slowly as the amount of cementite decreases. It is never 100 per cent complete, but may be called so, as only a trace of combined carbon, probably less than 0.10 per cent, is unchanged.

The raction noted above is occasioned solely by the temperature and time and is not affected by the presence or absence of packing materials. If, however, an oxidizing material, such as iron ore, is used for packing, another variable is introduced, that of decarburization. This decarburization results in a carbon-free surface layer of metal. A freshly fractured surface will show this bright carbon-free surface layer and a dark center. This type is known as black-heart castings.

When the castings are very thin in section, the decarburization may extend to the center of the piece. They are then known as white-heart malleable castings. The structure of white-heart castings is almost pure ferrite. In general, the physical properties are inferior to those of the black-heart castings. Aside from a limited production in Europe, white-heart castings are seldom encountered.

When a non-oxidizing packing material, or no packing material at all, is used, and when oxidation is wholly prevented, the casting may be known as "all-black," due to the absence of the decarburized surface.

Properties and Uses of Malleable Iron—In physical proper-

[4]Figs. 4, 5 and 6 from "Metallography of Iron and Steel," Dr. Albert Sauveur.

ties malleable castings are superior to gray cast iron and inferior to a mild steel. The tensile strength of commercial malleable is about 50,000 pounds per square inch. The elongation will range from 10 to 20 per cent in 2 inches. In regard to the resistance of the material to shear, impact, vibration, repeated impact and other stresses, the best evidence is the satisfactory way in which malleable castings stand up in service. The special field for malleable iron is its use for those parts for which a casting is required, but which must have more strength and ductility than gray iron.

Malleable iron, therefore, possesses the outstanding advantage of ease of melting and pouring, ease of machining and a fair strength and toughness. The simplicity and cheapness of melting and casting malleable iron has been sufficient to present serious encroachment upon the industry by steel castings.

Semi-Steel

Semi-steel is the name applied to a special grade of cast iron. The term semi-steel is, in reality, a misnomer, as the material bears no resemblance to steel in chemical composition, microstructure nor mechanical properties. The term probably originated from the fact that steel scrap is used in the charge. Semi-steel is made by melting pig iron, cast iron scrap and steel scrap in a cupola. After melting the metal is handled in much the same way as gray iron.

The Manufacture of Semi-Steel—The cupola is charged with about 50 per cent pig iron, 25 per cent scrap iron and 25 per cent mild steel scrap. This proportion is varied according to the requirements of the finished product. The charge is melted considerably hotter than if it consisted wholly of iron, hence coke consumption is relatively high. As the steel scrap reaches a temperature at which it becomes pasty it begins to absorb carbon. By the time it melts and becomes thoroughly mixed with the molten iron it has lost its identity as steel and contains between 2.00 and 3.00 per cent carbon.

The finished casting will contain between 2.50 and 3.50 per cent carbon, three-fourths of which will be in the form of graphite. The silicon content will vary between 1.50 and 2.50 per cent and the manganese between 0.50 and 0.80 per cent. Sulphur is usually less than 0.10 per cent and phosphorus about 0.50 per cent.

The composition of semi-steel depends upon the grade of iron used and the proportion of steel scrap used in the charge. This in turn depends upon the requirements of the finished casting. For light sections the proportion of steel is usually about 15 per cent; for heavier castings it may be as much as 40 per cent.

The Properties and Uses of Semi-Steel—Semi-steel has a tensile strength of about 35,000 pounds per square inch. The elongation in 2 inches is very low, often nil. The transverse loading test is extensively used to determine the quality. The transverse test piece adopted by the American Society for Testing Materials is a cast piece 15 inches long and 1¼ inches in diameter. The specimen is placed horizontally between two supports 12 inches apart and must withstand a load of 3800 pounds applied centrally. It must deflect 0.12 inch at the center under this load.

Semi-steel is superior to gray cast iron in tensile, compression and impact tests. It is more resistant to shock and wear than ordinary cast iron. The structure is close grained and uniform. The graphite occurs in very small particles. It machines easily. In structure semi-steel is more closely allied to malleable than to gray cast iron.

The combination of desirable properties, high strength, resistance to shock and easy machinability makes it especially suitable for cylinders, pistons, gears, hydraulic valves and like parts, where resistance to wear is important. It will stand high water pressures without leaking.

Semi-steel came into extended use during the war as a material for shells and aerial bombs. The material possesses a property known as fragmentation, or rapid and complete breaking up of the shell into small fragments. In this respect it is much better than steel. The use of semi-steel in peace times is restricted. Its use will surely increase in the future, as it can replace gray iron for castings, resulting in a material with much better mechanical properties and at only a slight increase in cost. At present semi-steel is regarded with considerable suspicion. This is due principally to the fact that it is not understood by the foundryman and, as a result, has been erratic and irregular in quality and properties.

REDUCING COSTS IN HEAT TREATING AUTOMOBILE PARTS

Abstract

This paper briefly outlines the present method of heat treating automobile parts in the plant of the Reo Motor Car Company, Lansing, Michigan, and describes the equipment now in use as contrasted with previous equipment.

Improved methods of handling together with more efficient heat treating equipment, automatically controlled, have resulted in large savings to this company.

Introduction

WITH the ever increasing demand for greater production and lower costs, progressive automobile manufacturers have realized the importance of increased efficiencies in production and especially in their heat treating departments. The necessity for a steady and adequate flow of finished materials is of great importance in the modern mass production and continuous "conveyor type" of assembly. Savings of a few cents here and there amount to surprisingly large sums of money over the period of a year. Such savings have made possible some of the present remarkable car values.

The management of the Reo Motor Car Company, Lansing, Michigan, has been far-sighted and alert to this need for greater economies in automobile manufacture. In the heat treating department of this plant have been installed many labor-saving devices and automatic systems, thereby lowering the cost of heat treating automobile parts and at the same time have decreased the percentage of materials spoiled during the processes of carburizing and heat treating.

It is the purpose of this paper to briefly describe the heat treating department of the Reo Motor Company and point out some of the reductions that have been made in manufacturing costs by the installation of more efficient heat treating and handling apparatus.

Materials Heat Treated

This company manufactures three types of motor cars, i. e., the motor bus, the light truck, and the pleasure car. The parts making up these three types of cars are essentially the same in

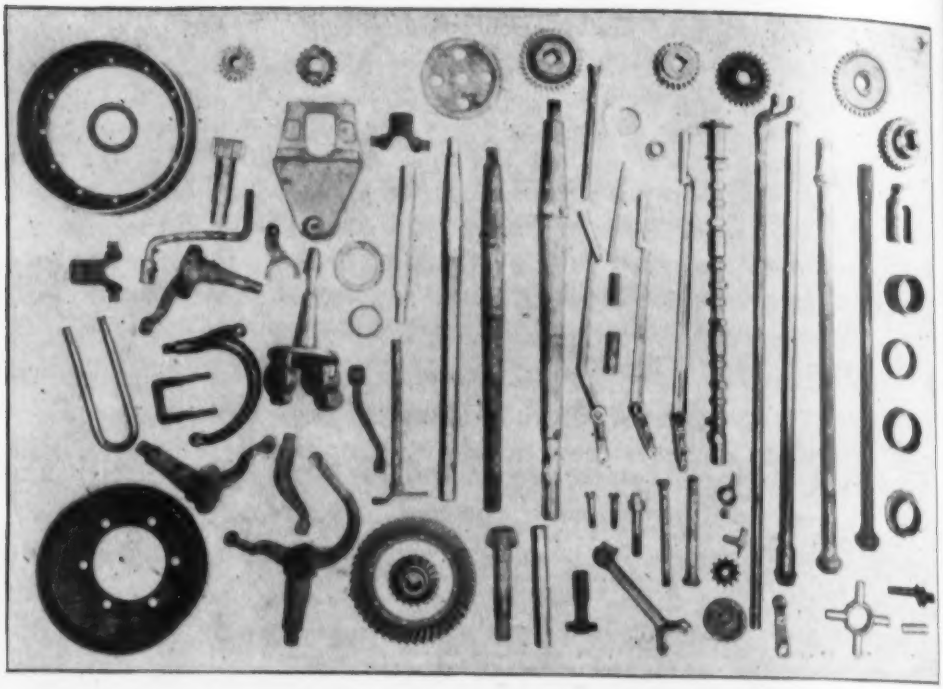


Fig. 1—Photograph of Automobile Parts, Some of Which are Carburized and the Others Heat Treated. The Heaviest Piece Shown in this Photograph Weighs Approximately 50 Pounds.

character but vary considerably in size and weight. While there are hundreds of parts composing a finished car, no attempt will be made to discuss them in detail, inasmuch as it is not the intent of this paper to discuss the heat treatments applied to each type but rather to show some of the savings which have been accomplished through better heat treating methods and equipment. However, Fig. 1 will give the reader a good idea of the large variety of parts needed in the construction of an automobile requiring heat treatment.

General Layout of Heat Treating Department

The building which houses the heat treating department is 300 feet long and 95 feet wide. The entire area of this building is not devoted to heat treating equipment, as may be seen in Fig. 2, however, all of the equipment is used incidentally to the heat treating department. The major portion of the heat treating apparatus is confined to about half of this area, i. e., a space approximately 52 feet wide by 300 feet long.

The floor plan (Fig. 2) shows the positions of the different

units of heat treating equipment which, in brief, consists of the following:

12—carburizing and annealing furnaces (oil-fired)
1—conveyor gear hardening furnace (electric resistor)
4—small hardening furnaces (oil-fired)
2—conveyor type hardening furnaces (oil-fired)
3—lead baths (20¼"x15½" deep) (oil-fired)
3—salt baths (26"x39"x11" deep) (oil-fired)
1—cyanide pot (37" long 13"x12¾" deep) (oil-fired)
5—cyanide salt baths (20" dia. x 8" deep) (oil-fired)
2—gear quenching machines
11—water quenching baths
7—oil quenching baths
13—recording potentiometers
17—recording control potentiometers
1—control potentiometer
2—carburizing box cooling turn tables

In addition to the above tabulation should be included carburizing boxes, two 3-ton electric lift trucks, quenching oil cooling system, one gas engine lift truck, eleven fuel oil storage tanks having a capacity of 72,000 gallons, one 9000-gallon quenching oil storage tank and the necessary pumps; also a carburizer sifting machine for the cleaning of used carburizers and a carburizing compound mixing machine.

Furnaces

The battery of twelve carburizing and annealing furnaces (Figs. 2 and 3) are of the under-fired type, using oil as fuel, and are automatically controlled with recording potentiometers (Fig. 4) and automatic oil-burner controls. The furnaces have a heating chamber space of 78 inches wide by 72 inches deep and a distance of 33½ inches to the top of the roof arch, which has a radius of 83 inches from the floor. Two different shapes of chromium-nickel alloy carburizing boxes are used: several sizes of rectangular pots and two sizes of the cylindrical chimney-type. These boxes have the "shoe-box" type of cover and are used without any luting compound. Each furnace accommodates from 12 to 18 of the rectangular type carburizing boxes and 16 of the chimney type, depending upon the size of the boxes. The largest of the rectangular boxes are used for carburizing cam shafts. There are three burners in each furnace and one thermocouple.

The thermocouple enters the furnace through the back wall and at a point directly above the boxes. These couples are checked once a day with a standard couple. The furnaces are operated

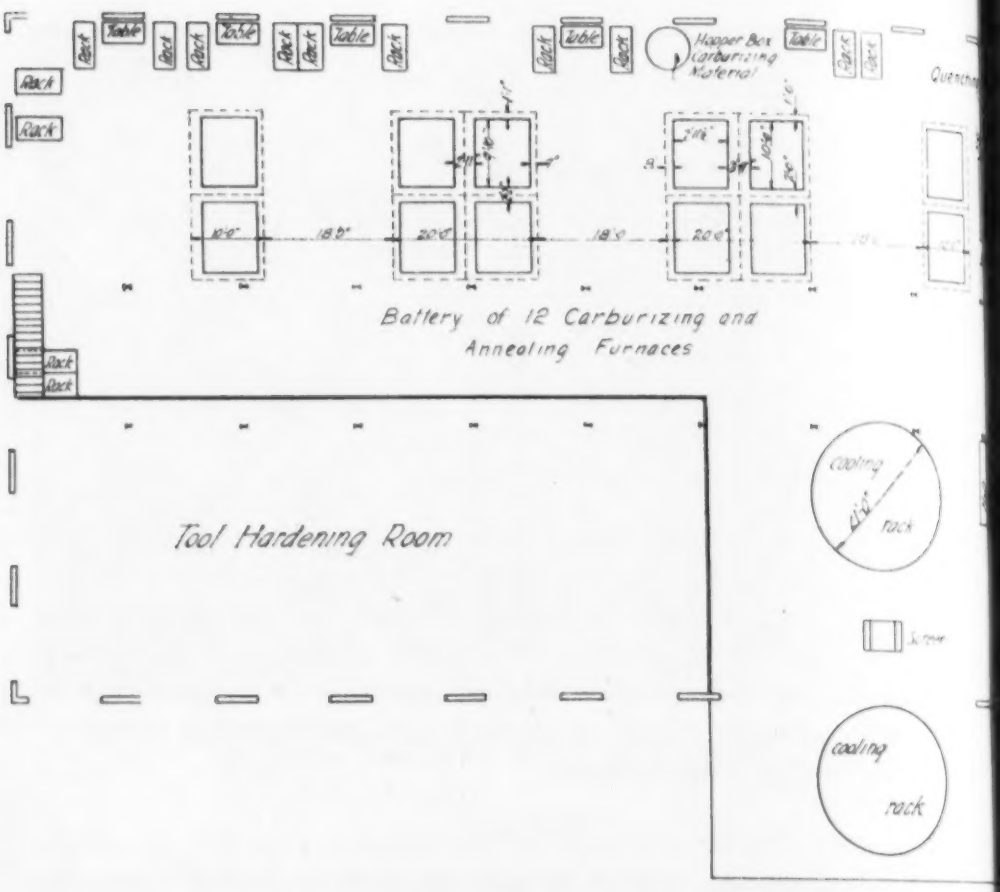
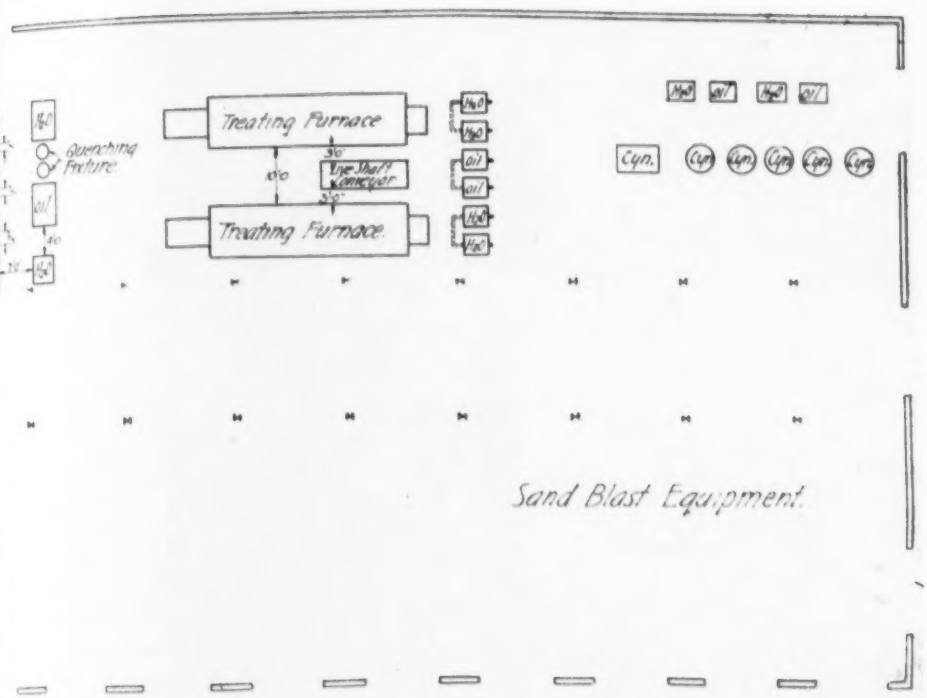


Fig. 2—Floor Plan of the Reo Motor Car Company Heat Treating Plant. The Over-all Dimensions of This Building are Approximately 300 Feet by 95 Feet. The Two Large Circular Cooling Racks Shown in the Lower Center are Designed in a Rotary Turn-table Fashion, so That They May be Revolved for Loading and Unloading.

24 hours per day and are attended by six men; three men on the day shift and three men on the night shift.

The electrically heated gear hardening furnace (Fig. 5) is operated by two men, one at the charging end and one at the discharge end. The furnace is used principally for hardening ring gears with the aid of the jig quenching machines. The three lead baths are operated by one man. The long continuous hardening and drawing furnaces (Figs. 6 and 7) are operated by five men, three on the hardening operation and two on the tempering process. The cyanide pots are operated by two men. At present this equipment is heat treating about 200 sets of parts per 24 hours. All of these furnaces are provided with automatic temperature con-



trols. The total labor required in the operation of the heat treating department amounts to twenty-nine men in 24 hours.

The carburizing boxes are at the present time packed in the basement beneath the hardening room and the boxes are elevated and trucked to the furnaces. Within a few weeks this method will be changed so that the boxes will be packed in the hardening room, as shown in Fig. 2. Four men are capable of packing all carburizing boxes.

The basement below the heat treating department serves in numerous capacities as a desirable adjunct to the hardening room. All of the carburizing boxes when they are unloaded are dumped upon a screen, thus separating the carburized parts from the compound. The compound passes through the screen down onto a power-driven riddle where the compound is sifted and freed of the undersized material and dust. From the riddle the compound is conveyed by air-tunnels to a mixing machine where the proper proportions of used compound are mixed with new compound. In some cases barium carbonate is added to the

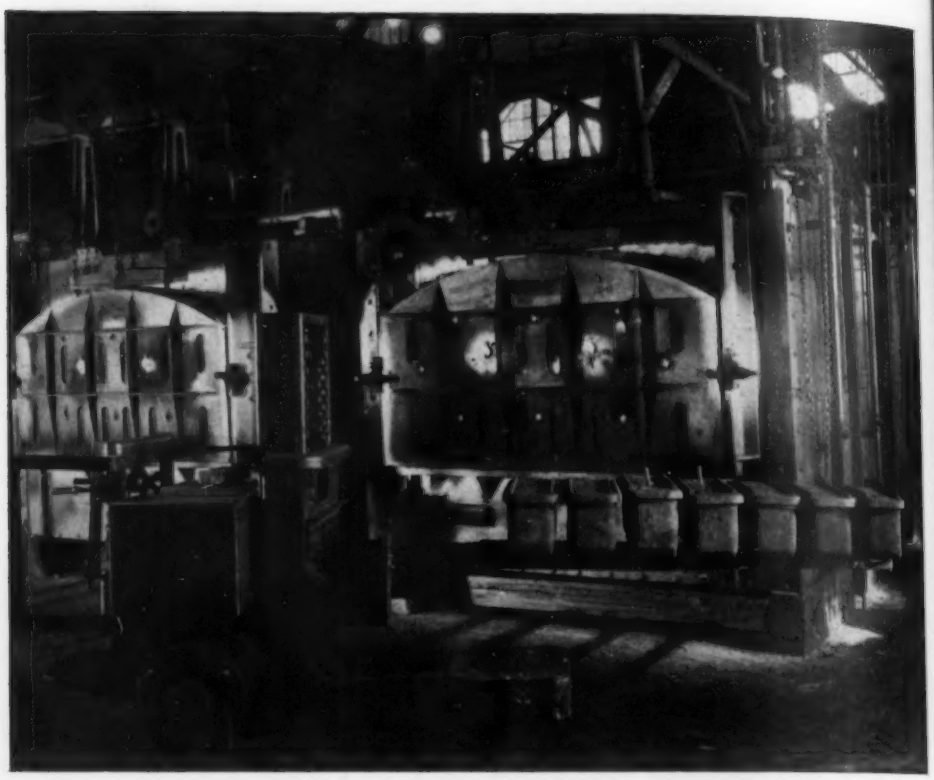


Fig. 3—Photograph of Two of the Large Oil-fired, Electrically Controlled Carburizing Furnaces, Showing the Electric Lift-truck with Carburizing Boxes on the Arm Ready for Charging Into the Furnace. Twelve of These Furnaces Constitute the Battery of Carburizing and Annealing Furnaces in This Plant. Each Furnace is Equipped with Three Oil Burners and One Thermocouple. These Furnaces are of the Under-fired Type and Operate at Temperatures Approximately 1700 Degrees Fahr. for Carburizing. The Heating Chamber Dimensions are 78 Inches Wide, 72 Inches Deep and 33½ Inches High.

Fig. 4—Bank of Twelve Recording Potentiometers Used for Controlling the Temperatures of the Twelve Carburizing Furnaces.

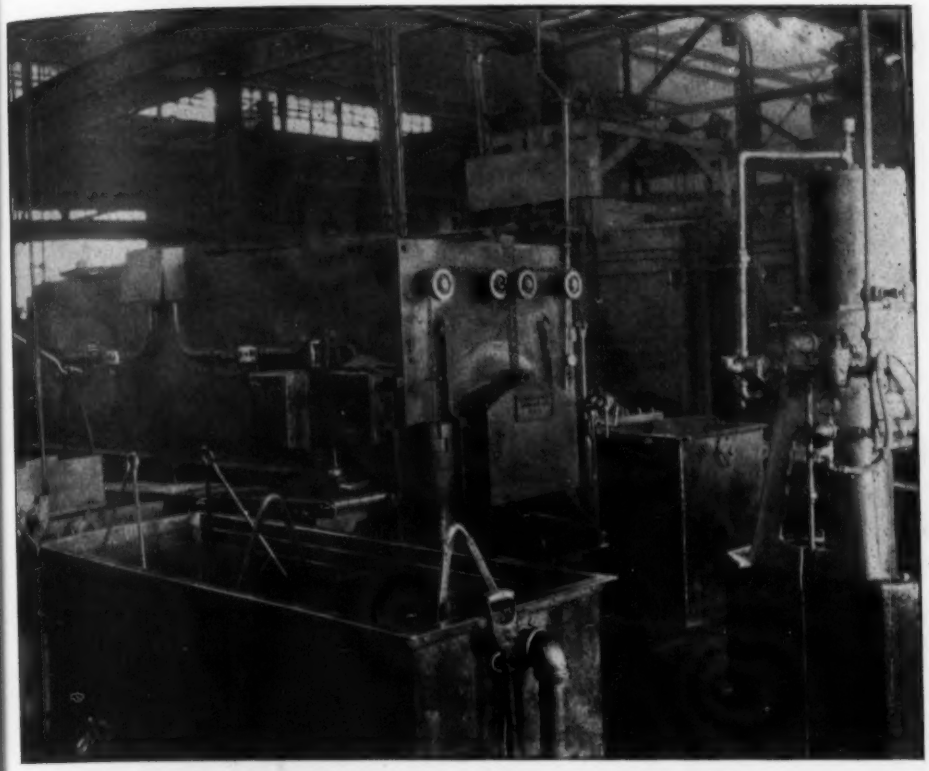


Fig. 5—View of the Electrical Resistor Furnace Used in Hardening All Gears. At the Right May be Seen One of the Two Jig Quenching Machines. This Furnace is Equipped with a Driven Roller Hearth which Carries the Gears Through the Furnace at Such a Speed That They are Up to the Proper Temperature by the Time They Reach the Discharge End. Two Men Operate This Furnace—One at the Charging End and One at the Discharge End. The Hearth of This Furnace is 16¾ Inches Wide by 16 Feet Long.

used compound to energize it properly. From the mixing machine the compound is conveyed through air-tunnels to the storage hopper.

The quenching oil cooling system and storage tank is likewise located in the basement, together with the necessary pumps, clean-out traps, etc. The oil pumps for pumping the fuel oil from the storage tanks are also installed here.

Furnace Operation

Prior to the installation of the first six carburizing furnaces in April, 1925, a battery of twenty-two furnaces was in operation. These twenty-two furnaces were approximately equal to eight of the new type. Due to the type and design, these twenty-two furnaces required fourteen men in 24 hours for their operation. The amount of spoiled work was approximately 3 per cent. In September, 1925, six additional carburizing and annealing fur-

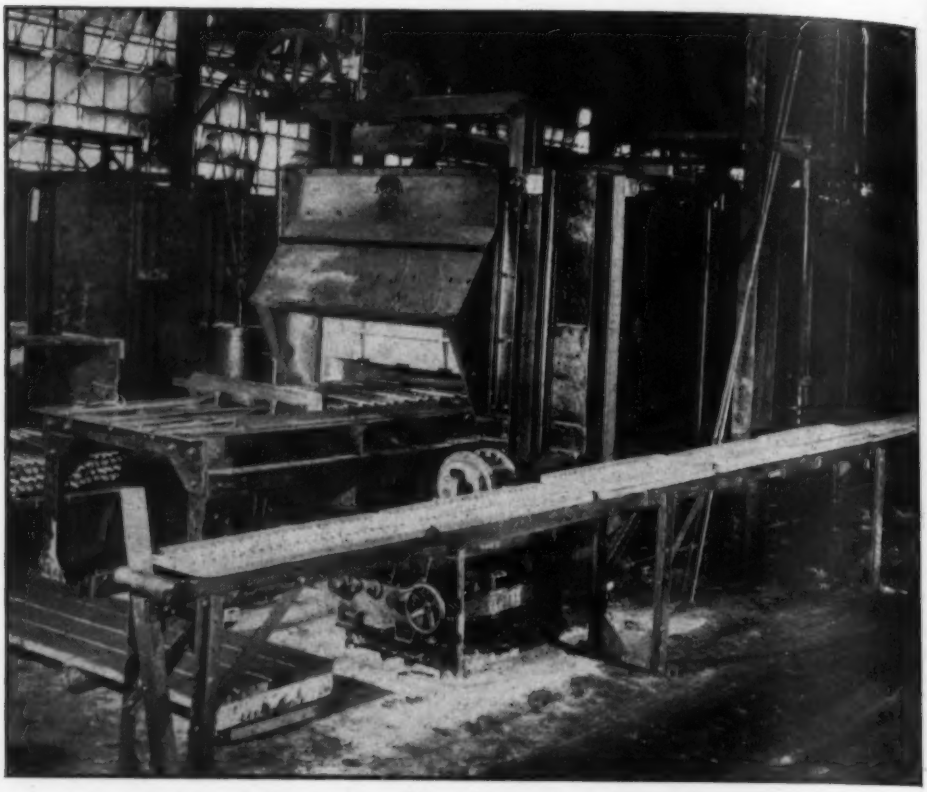


Fig. 6—Charging End of the Semi-continuous Conveyor Type of Hardening Furnace Used Principally for the Heat Treatment of Rear Axle Drive Shafts. In the Foreground May be Seen the Nickel-chromium Alloy Trays on which the Shafts are Laid. The Conveyor Mechanism is of the Intermittent Pusher Type. This Furnace is of the Under-fired Type, Having Six Automatically Controlled Oil-burners. Three Men are Required for Its Operation, One on the Charge End and Two on the Discharge End. The Hearth Dimensions of This Furnace are 45 Inches Wide by 18 Inches High and 25½ Feet Long.

naces were installed and the total number of men required to operate the twelve furnaces (a 25 per cent increase in capacity over the former installation) is six for 24 hours. The quantity of spoiled material has dropped to less than 1 per cent, due to more accurate temperature control and more efficient methods of handling.

It is estimated that, due to the replacing of the previous manual-control oil-burner furnaces with this new equipment and introducing more efficient methods of handling, a minimum saving of $15,000 per year in wages has been made.

During the period of operation of these furnaces there has never been any interruption excepting the usual shut-down at the end of each week. Accurate records have been kept of the production of the carburizing and annealing furnaces and the following is the result of a 9½-day run (January, 1926) selected at

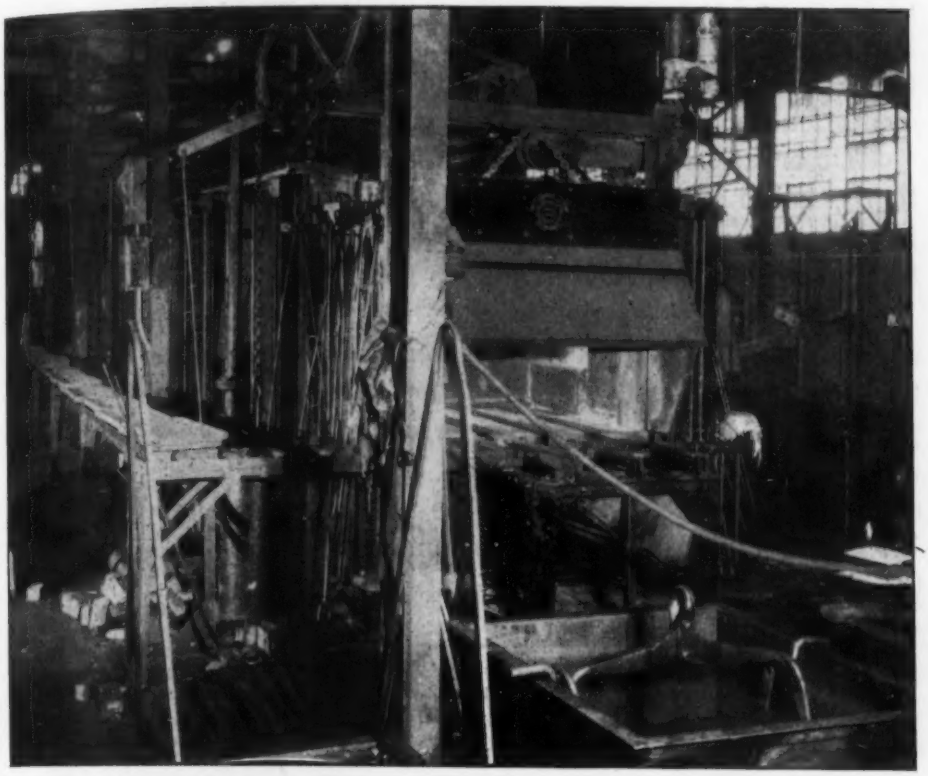


Fig. 7—Showing the Discharge End of the Furnace in Fig. 6. The Quenching Tank at the Right Between the Two Furnaces is of the Inclined Rail-type, Having a Conveyor for Removing the Axle Shafts from the Quenching Bath.

random. The total net weight of parts carburized was 138.6 tons, or a daily average of 14.59 net tons per 24 hours. This results in a figure of 1.21 net tons of carburized parts per furnace per 24 hours. When we consider the various sizes of the parts carburized and the low fuel oil consumption of the furnace (7.1 gallons per hour), together with the low percentage of spoiled material, the efficiency of these furnaces is remarkable.

An accurate test was made a few weeks ago of the fuel cost of one of the carburizing furnaces operating continuously for a period of 82¾ hours.

It required 8.5 hours to bring the furnace and charge up to a temperature of 1700 degrees Fahr., and in doing so consumed 665 pounds of fuel oil, an average of 78 pounds per hour. The hot fuel (approximately 170 degrees Fahr.) used, weighed 7.2 pounds per gallon, hence the volumetric consumption while bringing up to heat averaged 10.8 gallons per hour. Observations made during the fifth and seventh charge showed that the consumption

of oil while the furnace was being brought up to heat after charging, averaged 81 pounds per hour. It can, therefore, be concluded that the average consumption of oil while the burners are burning continuously averaged 80 pounds per hour, or 11 gallons per hour.

Observations made while the burners were burning intermittently holding the temperature (1700 degrees Fahr.) after the furnace and charge were up to heat showed an average consumption of 40 pounds per hour, or 5.5 gallons per hour.

During the test, the furnace was charged seven times. An effort was made to pick such materials as would be a representative average charge going into the furnace in regular everyday production. The first batch was heated before the furnace was up to heat and this undoubtedly explains the length of time required in coming up to heat. Up to the time of the first charge, 100 pounds of oil had been consumed. The following table gives the size of charge and the oil consumption per charge.

Charge	Wgt. Boxes	Wgt. Comp.	Net Wgt. Parts	Gr. Wgt.	Hrs. Run	Oil Consp. Lbs.
1	2526	490	616	3632	13.0	892
2	2964	658	1485	5107	17.0	787
3	2521	378	1260	4159	11.75	601
4	2521	434	2254	5209	10.25	514
5	2277	464	1008	3749	8.75	439
6	2506	462	1264	4232	11.75	555
7	2475	462	1596	4533	10.25	449
Total	17790	3348	9483	30621	82.75	4237
Aver.	2541	478	1355	4374	.....	...

4237 pounds of oil equal 588.5 gallons.

		Pounds
Oil used		4237
Time in hours	82.75	
Average oil consumption per hour		51.2
Average oil consumption in gallons per hour	7.11	
Gross weight heat treated		30621
Weight boxes and lids		17790
Weight compound		3348
Net weight		9483
Net weight heat treated per pound of oil		2.23
Net weight heat treated per gallon of oil		16.06
Gross weight heat treated per pound of oil		7.22
Gross weight heat treated per gallon of oil		51.98

Fuel oil during weeks of January 4 to 11 cost $.0619 per gallon average

588.5 gallons @ $.0619	$36.43
Therefore Fuel cost per net pound heat treated	$ 0.00384
Fuel cost per gross pounds heat treated	$ 0.0011

It is, of course, realized that the above figures are not net

cost figures for carburizing, because to these figures must be added such items as:

Initial installation cost	Interest and depreciation
Cost of maintenance	Rent for building space occupied
Labor	General overhead

With this installation the percentage of rejections have been much decreased. All carburized and heat parts are inspected 100 per cent for hardness and in the case of camshafts they are inspected 100 per cent on every cam and bearing, and must show a sclero-scope reading of 80-90.

Continuous Hardening Furnaces

The two continuous, hardening and drawing furnaces, are oil-fired and of the under-fired type. They are semi-continuous, using a pusher system of conveyor with chromium-nickel alloy trays and chromium-nickel rails in the furnace. These furnaces were supposed to heat for hardening 1 ton per hour and a 5-day test of one of them showed a net weight production of 232,277 pounds. This is equivalent to a net weight of heat treated material per hour of 1941 pounds, or within 59 pounds of 1 ton per hour. Production of 1 ton per hour in the heating of materials to approximately 1500 degrees Fahr. in a furnace 26 feet 6 inches long and 42 inches wide and 18 inches high, with the heaviest material not exceeding 50 pounds in weight, is indeed very good efficiency. Figures for fuel cost were not available.

The entire installation of equipment in this heat treating plant is of the most modern design and combined with it is an adequate system of handling the materials to be heated, by means of electric lift trucks. Also all of the furnaces are supplied with automatic temperature controls, thereby eliminating much of the personnel used in the earlier installation, and insuring more accurate control of the temperatures of the furnace. It is through this method of improved handling of parts to be heated and a more accurate control of furnace temperature that higher fuel efficiencies are obtained and the amount of spoiled material reduced.

With these improved methods of handling and the installation of larger and more efficient furnaces, the Reo Motor Car Company has made a large saving in wages and rejections and has increased the quantity of materials heat treated. This increase in production has resulted in a large decrease in cost of production over the period of time during which this new method has been in operation.

CUTTING

By W. R. Ward

Abstract

In the cutting of materials force must be applied either to the cutting tool or to the material being cut in order that the tensile strength of the material may be exceeded as the edge of the tool advances and ruptures the fibers. The angle at which the force is applied is significant.

A thin wedge-shaped tool reduces the wedge resistance and allows more force to be applied on the cutting edge.

For hard substances a more blunt wedge-shaped tool is necessary than for soft fibrous materials.

WHEN a sharp edge-tool of any of the various shapes is forced into a material, the action is ordinarily known as cutting. A knife may be forced directly into a material or drawn across it, or given a chopping blow; in any case the edge enters the material being cut. In doing so, just what takes place independent of the source of power applied to the cutting knife or tool? The action is mainly that of applying a localized force to the material to that point where the tensile strength is exceeded, and also using the action of a wedge to force the material open so that the edge of the tool can again exert an intensified force on the next fibers causing them also to rupture under tension. The wedging open of the cut causes bending and compressive strains on the adjacent material on each side of the cutting edge and in some cases a shearing action is included. However complex the various strains may be, the main one that causes the edge to advance is that of overcoming the tensile strength of the material.

By way of illustrating this discussion we shall use two materials, wood and steel.

If we chop into a tree, the blade of the axe is forced into the wood by the force of the blow. The edge having a small surface of contact, exerts an intense force on the fibers it comes in contact with, forcing them against the next fibers until they are stretched to the breaking point, thus allowing the edge to come in contact with other fibers. This goes on until the force of the blow is

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expended not only in severing the fibers, but in wedging them apart. It will be noted that if the blow is perpendicular to the grain of the wood the axe does not penetrate as deeply as though it were to strike at an angle. In the latter case, the wood on the obtuse angle side of the axe raises up, as shown in Fig. 1. The wood bends and splits somewhat on this side in making room for the axe. On the other side only a compressive action is exerted on the fibers, so no splitting or bending takes place.

Now to bring out the point of tension, if we bend a small tree

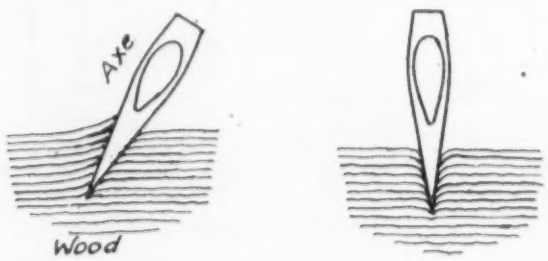


Fig. 1—Showing the Method of Penetration of an Axe in a Piece of Wood, when Struck a Perpendicular and Oblique Blow.

and chop on the concave side, little effect will take place, because the fibers are in compression on this side, and in order that the cutting edge may exert tension on them, it must first press the fibers into the wood until a state of tension exists and is exceeded before the edge can advance. To do this the wood resists the wedging action of the axe with great force. If, however, we strike a blow on the convex side where the wood fibers are in tension, it takes little additional tension on them to rupture them, and the bending action opens the cut, allowing the edge to advance to the other fibers without biting on the sides of the axe, as in the former case.

This simple case demonstrates that the cutting action is simply a case of overcoming progressively the tensile strength of the material as the edge of the tool advances.

A dull tool will cut, but of course requires more force than is needed for a sharp tool. This is only a case of more area of contact of the tool with the material being cut. Let us go the limit and use a blunt tool, say a hammer. If a piece of wood is struck a very heavy blow, the hammer will in the case of a small long piece of wood, break the piece (the fibers on the far side parting first) or in the case of a large piece, a dent will be made.

In the first case the force is transmitted in such a way as to cause a bending moment which ruptures the beam, and in the second case the inertia of the large piece of wood localizes the strains to the fibers surrounding and in front of the hammer head surface. Those just in front are forced against adjacent layers and that portion at or near the edges of the hammer face (let us say a rounded face hammer is used) are put under tension, if the blow

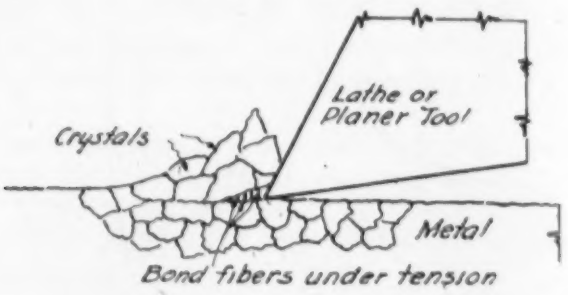


Fig. 2—Showing the Mechanism of Cutting a Piece of Metal with Lathe or Planer Tool.

is great enough to the point of rupture. This is a case of extreme surface of contact requiring great force to put sufficient tension in the material to cause rupture.

It will be noted, that it is difficult to cut spongy wood. The fibers "give" or elongate before being cut, also there is no support between the layers to hold them in place when the axe enters. The axe soon wedges after cutting the outer fibers. The fibers in the spongy wood when cut are similar to vines that have to be stretched to some point of resistance before they will break from tension. For this reason some of the hard woods can be cut more easily than softer spongy woods.

Now let us look into the cutting action on metals, such as steel. With rolled or drawn stock we may speak of the metal as having grain or strain lines, however the metal may be homogeneous in structure. Assuming that the metal is softer than the cutting tool and cuts are made, the action is similar to that described in the case of wood, with the exception that the material does not have such pronounced fibers or grain. Here we may have a fibrous metal or one of coarse crystalline structure.

With fibrous metal the tool forces the fibers until the tensile strength is exceeded and the metal is wedged open so the tool can reach and rupture other fibers. Fibrous metal is tough and will

bend considerably before enough tension is exerted to break the fibers, therefore the chip will generally stay intact and not crumble; it only bends out of the way of the tool as the latter advances. This bending action acts as the main resistance to the tool. Try a piece of 30 per cent (not 0.30 per cent) nickel steel and a piece of 0.50 per cent carbon steel and turn them on a lathe, using the same sizes and depths of cuts; then note the amount of electrical current the lathe motor uses in the two cases.

With a harder and more crystalline piece of steel to be cut,

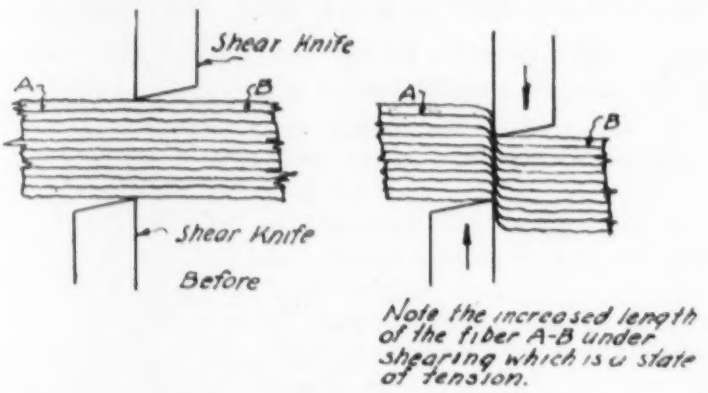


Fig. 3—Showing the Distortion and Extension of the Fibers of a Piece of Steel when being Sheared.

we have a case of the cutting tool acting as above where the metal comes in contact with the edge of the tool, but it is believed that when a cut is once started, the wedge action of the tool forces the particles of metal apart and the crumbly chip evidences that the fibers (if we may call them that) or crystals, are bent until they are broken by the wedging action, the edge of the tool may hardly exert much force before the wedging of the metal breaks a chip off. Here the crystals are not held together in a fibrous manner, but are cemented together by a bond. They are forced past each other until this bond is broken; some are wedged apart. If the situation is looked upon from a microscopic view point, the fibers of the crystal bonds will be broken from the tension put upon them. Fig. 2.

A thin wedge shape on a tool reduces the wedge resistance and allows more force to be applied on the cutting edge. For hard metal the pressure reaction on the tool from the metal being cut may cause too much force on the thin wedge edge support and cause it to crumble instead of holding the edge in the cut; there-

fore for hard metal a more blunt wedge shape to support the cutting edge would be necessary.

In studying any cutting action, the writer finds it difficult to expel the question of rupture by tension, irrespective of the shape or type of cutting tool used, shearing action being included. The method of applying force to the cutting tool or tools does not alter the action or the principle of cutting. Whether the material is forced against the tool as is the case of a lathe tool, or the tool is forced into the material as in the case of a cold chisel, or the cutting edge strikes a blow as a saw tooth, the edge exerts a localized tension on the material in the case of a sharp tool and more general in the case of a blunt tool.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

HARD SPOTS ON STEEL FORGINGS. John D. Gat, research metallurgist, United Alloy Steel Corporation, Canton, Ohio, in *Forgings, Stamping, Heat Treating*, January, 1926:

The author of this article in his study of the phenomena connected with the formation of hard spots on the surface of a forging die, deduced from various experiments certain generalizations and facts which he used as a basis for further investigation and to establish a cause for the trouble as well as to recommend methods for its prevention.

He observes that hard spots are not due to segregation; but that a sharp line of demarcation exists between hard spots and segregations found at times in high carbon, high alloy steels.

Where not subjected to thermal treatment, hardening of small spots on the surface does not occur; neither are hard spots peculiar to any definite type of steel. As they appear only on the surface, and are never numerous enough to affect appreciably the production of a plant, their importance has been greatly exaggerated.

Under a microscope hard spots resemble flakes of cast iron, and evidence would tend to prove that every hard spot starts with a flake of cast iron.

To avoid the possibility of contamination with carbon in the conducting of these experiments, careful scrutiny was exercised in the selection of molds and utensils used. Upon the completion of this experiment, a rigid investigation showed that there was no contamination from ingot molds.

Heating in soaking pits was found to be totally irresponsible for carbon contamination.

After the final rolling, the billets were carefully inspected and chipped. A thorough inspection of a ground surface is necessary as hard spots are not easily detected by a casual examination. After an exhaustive inspection by expert examiners failed to show a single hard spot in steel made according to the processes above set forth, the conclusion was reached that hard spots do not originate in the manufacture of steel but are produced in forging plants.

Elimination of the possibility of carbon coming in contact with heated blanks by the use of heating furnaces of proper design will obviate this trouble.

PULVERIZES COAL AT THE FURNACE. By E. C. Kreutzberg, in *Iron Trade Review*, January 28, 1926.

This article sets forth that the pulverizing of coal for immediate use

in the furnace or oven unit to which it is attached results in a reduced production cost in the malleable castings industry. This is accomplished by a new type of coal pulverizer directly connected to the consuming unit and known as a unit pulverizer. While there are no definite figures existing, a saving is claimed of considerably more than 25 per cent in the total melting cost as against the cost of operating a hand-fired furnace. Not only is there a saving in the cost of melting, coal, labor, ash disposal, etc., but the reduction in the furnace loss is also appreciable.

These findings are the result of an investigation made at the plant of the Kuebler Foundries, Inc., Easton, Pa., early in 1925. Even though exact figures on operation are not available, its adoption by other concerns would indicate its feasibility. The article describes the experiment at the above mentioned plant setting forth the method of operation and illustrating it with three reproduced photographs.

The advantages of this method are: Although the same grade of coal is used it need not be so finely screened; there is almost an entirely negligible amount of ash; the temperature of the furnace can be raised to a desired heat more quickly than in the old way, the heat is more easily controlled, and turned out in less time.

SCIENTIFIC AND EXPERIMENTAL RESEARCHES ON SPECIAL STEELS. By E. Sommer and E. Rapatz, *Revue de Metallurgie*, November, 1925. Translated and abstracted by Frederick W. Shaw of Sheffield, England.

Applied scientific methods are replacing the former trial and error processes and result in more economic manufacture. The results of experiments in testing laboratories must, of necessity, be available for use in the immediate future; whereas, findings resulting from experiments in purely scientific institutions are more theoretical, and consequently not adapted for immediate application.

The research laboratories perform two important tasks: conducting a study of the composition of steel in course of manufacture based upon past knowledge and experience, and experimenting with new combinations.

Chemical analysis is an absolute necessity for all kinds of steel, but the proportion of certain impurities, such as oxygen, nitrogen, or hydrogen, are difficult to determine. Neither will it show defects, such as piping, cracks, segregations, etc.; nor will it show the effect of previous heat treatments. Hence, chemical composition cannot determine that a heat of steel is suitable for a definite application.

Physical tests consist of determining the new characteristics in tensile strength, elongation, reduction of area, elastic limit, proportional limit, modulus of elasticity and, by way of more and more important extension, resiliency or re-bound. These characteristics are of fundamental importance for constructional steels, but for tool steel the features obtained by tensile and shock-testing are of no value, inasmuch as the quality of the material depends chiefly upon other properties.

Hardness tests are only of secondary importance from a practical point of view, particularly for ascertaining the coefficients of the material.

For hardened steels, the bending test on hardened specimens is of great

importance. This is the usual test on steels for ball bearings, and supplies the measure of their tenacity. The most important test for tool steels is the hardness test after annealing and ball-hardness by pressure or rebound.

In general, when the resistance to a certain limit, the cutting-speed may be increased, and the work done more economically, but the annealing may be carried too far and entail a coarsening of grain and surface decarburization. Therefore, a fixed ratio exists between decrease of resistance, increase of speed cutting, quality of the steel, and obtaining a perfectly smooth cutting surface.

The macroscopic inspection of surfaces etched by various reagents and microscopic inspection on polished and etched specimens has become indispensable for studying the phenomena of solidification, rolling, forging, annealing, and improving of the steel, as well as for the discovery of certain defects.

The thermal study of alterations in structure of special steels, while not in current practice, is of value in determining the structural changes in steel of known or new chemical composition.

Repetition tests, owing to variety of manufacture, are infrequently used, but they have value in determining the relations existing between variation in proportion of nickel and flakings in steels for rifle-barrels.

The X-ray test, owing to its limited power of penetrating the thickness of steel, is of little importance.

Scientific tests in laboratories should be followed by practical tests in the works. Theories can there be worked out in a practical way and will result in showing the defects, if any exist. By a series of technological tests, it can be ascertained whether the steel is suited to its use.

Present knowledge of the properties of existing kinds of steel is limited in regard to the influence of the various elements of alloys upon these characteristics, variety of opinions on heat treating is proof of this.

Evidence points undeniably to the conclusion that purely scientific and theoretical progress may best be accomplished when the research and testing laboratories work together. The economic, as well as the scientific, purpose must be kept in mind and will be best served through co-operation.

RELATION OF HEATING VALUE OF GAS TO ITS VALUE TO THE USER. E. R. Weaver, Chemist, B of Stan. Washington, D. C., *Chemical and Metallurgical Engineering*, February, 1926.

The value of commercial gases, not containing too large a quantity of inerts, is directly proportional to their heating value.

The thing that interests the user of gas is the amount of potential heat he can purchase at a known price. The other properties of gas are unimportant to him.

A careful study of statistical data would seem to indicate that the volume of gas used varies nearly, if not exactly, in inverse proportion to the heating value. Changes of heating value do not affect greatly the amount of heat used by a community. A seasonal variation in the use of gas obtains in nearly every community.

A comparison made over a period of several years in many localities will determine quite a definite quantitative relation between the change of heating value and the change of consumption which resulted. "When any

of the commercial combustible gases is burned with air under favorable conditions the hottest part of the flame has about the same temperature for each gas.''

A gas mantle will give most light when it ''coincides with the flame.'' Hence the usefulness of gas to the consumer is directly proportional to its heating value.

THE VOLUME CHANGE IN THE SPECIAL STEELS DURING HARDENING. By M. G. Oknoff. *Proceedings* of the second Congress of

Table I

Classes of Steel	Kinds of Steel	Contents in Per Cent								Maximum Change of Specific Volume at hardening in %
		C	Si	Mn	S	P	Cr	Ni	W	
Pearlitic	Nickel steel, soft..	0.19	0.19	0.66	0.015	0.016	.....	4.24	.....	+0.09
	Nickel steel for springs	0.47	0.42	0.61	0.025	0.026	.....	1.41	.....	+0.60
	Nickel steel.....	0.52	0.25	0.50	0.009	0.023	.....	2.65	.....	+0.54
	Chromium steel for ball bearings....	1.12	0.31	0.36	0.011	0.024	1.20	.....	.....	+0.85
	Chromium steel for ball bearings....	1.01	0.27	0.40	0.012	0.016	1.21	.....	.....	+0.97
	Chromium nickel steel, soft	0.16	0.27	0.37	0.010	0.020	0.88	3.87	.....	+0.19
	Chromium nickel steel, soft	0.17	0.18	0.10	0.025	0.021	1.17	5.11	.....	+0.18
	Chromium nickel steel, soft	0.21	....	....	.....	.....	0.77	3.69	.....	+0.30
	Chromium nickel steel, hard	0.54	0.22	0.53	.....	0.036	1.24	3.14	.....	+0.60
	Chromium nickel steel, hard	0.56	....	....	.....	.....	0.19	1.15	.....	+0.54
Martensitic	Manganese steel, hard	1.79	....	2.0	.....	0.016	.....	.....	.....	—0.19
	Nickel steel, nonmagnetic	0.32	0.38	0.36	0.045	.....	.....	22.8	.....	—0.83
Austenitic	Manganese steel of Hadfield	0.93	0.13	1.02	Tr.	0.06	.....	.....	.....	.....
	Chromium nickel steel, nonmagnetic	0.46	0.29	0.26	0.013	.....	2.72	22.56	.....	.....
Carbide Class	Chromium steel, hard	1.65	....	....	.....	.....	2.0	.....	.....	—0.54
	Chromium steel, stainless	1.00	0.10	0.19	0.020	.....	14.18	.....	.....	—1.45
	High speed steel..	0.47	0.07	0.27	.....	.....	2.95	.....	11.3	+0.38
	High speed steel..	0.59	0.80	0.25	0.035	.....	5.15	.....	16.66	+0.41
	High speed steel..	0.68	0.36	0.45	.....	.....	3.54	.....	16.3	+0.48

Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 119.

Special steels of different composition were hardened at various temperatures and by way of defining their specific gravity before and after quenching the corresponding changes of volume were found. The composition of the investigated steels and the maximum changes in their volumes are given in Table 1. As one sees in it, the volume of the steels of the pearlite class changes during the hardening proportionally to the contents of carbon, the magnitude of this change being the same as in carbon steels, i. e., about 0.1 per cent for every 0.1 per cent carbon. The change of volume in steels of the carbide class is dependent upon the temperature of hardening. At low tempera-

tures, only one part of carbide passing into solid solution, the latter is changed into martensite and such an increase of volume observed approximately as in carbon steels. With the rise of the temperature of quenching, the increase of the volume becomes less, then becomes equal to 0 and finally at the highest temperatures of hardening a decrease of volume takes place. In the latter case the structure of steels consists of austenite. A decrease of volume is always to be observed during hardening in the steels of the martensite class, for the reason that at the heating the martensite with a large volume is transformed into the austenite of small volume which is then fixed by quenching. Finally, the austenitic steels do not show any change of volume at the hardening, because there happens to be no change in their structure at this time.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

AN UNTOUCHED MARKET FOR STEEL. By Prentice Winchell, *Iron Age*, February 4, 1926, page 333.

The author in his article calls attention to the vast new field for sheet steel in the manufacture of metal motor boats which will replace the old wooden type. This industrial revolution will, of necessity, result in a change from individual construction to manufacture on a large scale. Standardization will reduce the cost, and boat manufacturing will replace boat building. This, together with dealer-distribution, will rapidly develop a market for steel boats, as is evidenced by the tremendous growth in the automobile industry when this state of affairs came into existence. Manufacturing in large numbers will demonstrate the economy in the use of steel. Stainless steel will eliminate corrosion, and danger of puncture is negligible in view of the fact that a damaged sheet can be quickly removed and replaced with another. The beauty of the boat will remain the same as the most successful wooden boat, because it will be built on the same lines. The metal boat will be stronger, also lighter, which will result in a saving of power and gain in speed; its cost will be less than a wooden boat and a lower insurance rate will obtain, especially where gasoline is used as power.

It is estimated that there were about 750,000 motor boats in use last year. The life of such boats is from 15 to 20 years. Consequently there is need for about 35,000 new boats annually. Newer and less expensive boats, together with a definite creation of demand for them, will increase tremendously the sale. Also with the increasing population along all waterways and the establishing of pleasure resorts on the shores of waterways, a 100,000 market is almost a certainty. This means a tremendous market for the manufacturer of stainless steel, rivets, welding equipment, tools, etc.

The day of the metal motor boat is here.

COMBINED CASTING OF STEEL AND THE METHOD FOR THE COMPRESSION OF THE LATTER. By A. Z. Roshkoff. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 97.

A casting mold, divided in two parts vertically by a flat or annular iron diaphragm is filled simultaneously with steel of different chemical composition, the result being a 2-layered ingot, with one side consisting of hard steel,

the other of soft one. In this way one can get 3-layer ingots with two hard surfaces and a soft interior part. For a closer joining of the two different layers of steel, the ingots besides being drawn are compressed by forging or stamping. *M. Oknoff and G. N. Koulginski, Leningrad, Russia.*

THE STUDY OF THE HARDENING OF LARGE PIECES OF STEEL. By N. F. Goudtzoff and P. K. Silnitzki. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 108.

The rate of the drop in temperature during the hardening of large pieces of steel was studied. Readings were taken on the surface and at the depth of 20, 40, 60, 80 and 100 millimeters in from the surface. The speed of cooling gradually decreases from the periphery to the center. The original temperature of the hardening decreases in the same direction. In connection with this a gradual decreasing of the hardness of steel is observed from the maximum on the surface to the minimum in the center. There is never observed a sharp limit between the hardened and the unhardened layers. The velocity of decreasing of hardness and the speed of change from martensite into pearlite varies in different kinds of steel. The admixture of manganese (from 1.5 per cent) visibly augments the hardness of the surface layers alone and does not affect the hardness of the interior ones. As to nickel (4%-5%) it augments the hardness not only of the hardened surface, but the interior layers also to the depth of 100 millimeters.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

INFLUENCE OF THE STRUCTURE OF ANNEALING ON THE HARDENING OF TOOL STEEL. By S. K. Iljynski. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 161.

Tool steel (carbon 0.92 per cent; silicon 0.24 per cent; manganese 0.4 per cent) before being quenched was annealed at 660, 730, 740 and 750 degrees Cent.; the structure of granular pearlite was attained to a greater or lesser degree according to the temperature and speed of the further cooling and the Brinell hardness changed from 241-143. The larger the quantity of granular pearlite in the steel, the lower its hardness. This is explained by slow passing of the granular pearlite into austenite and by incomplete dissolving of Fe_3C in the ordinary conditions of heating before quenching. The satisfactory hardening of the steel investigated was attained in the case, when the Brinell hardness of it before quenching was not less than 200.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

MAKING OF HIGH GRADE STEEL IV. By John A. Coyle. *Iron Trade Review*, January 28, 1926, page 261.

Production of this commodity is hampered by many difficulties which, together with the present methods of buying, result in high cost of high speed steel.

High speed steel is the greatest advance in high grade steel making, as evidenced in the industrial world of today. A study of the chemical analyses of steel throughout its range of development from the pre-Mushet era carbon steel to the chemistry of high speed steel, shows its growth and trend. It has been found that when it can be controlled in content, uranium adds to the art of high speed steel making.

Individual opinions and whims of purchasers embarrass manufacturers of high speed steel, consequently a more general recognition of standards would be of advantage.

The various brands of high speed steel will not show enough difference in the cutting speed and feed to warrant a change in the source of supply. Time will change this, however.

The method of producing the best high speed steel and the attaining of superior results in its making are outlined by the author. He points out to the manufacturer and user the detrimental results of using the finishing hammer and sets forth the gain in quality of product and saving in money when the rolling process is used.

Proper inspection for defects prior to annealing must be made to avoid waste. After the manufacturer has exercised care in the making of the product, it is the customers' duty to guard his processes, in order to avoid economic waste. Care and eternal vigilance all along the line, from the inception of the process of high speed steel to its ultimate use, will have a tendency to keep the price down, while failure in these matters will continually add to its cost.

It is considered that many advantages would accrue to an association of producers of high speed steel, especially along the lines of sales problems and control of standardization in the making of high speed steel.

THE STRUCTURE AND HEAT TREATMENT OF CAST STEEL. By S. W. Belynski. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 102.

Cast steel consists of primary dendrites surrounded by an envelope of secondary ferrite or cementite; the fact of the existence of these mentioned envelopes is the cause of the brittleness of this steel. For the complete dissolving of these envelopes it is not enough to heat the steel a little over Ac_3, but a heating up to 1100-1300 degrees Cent. is required. A new ferrite or cementite network appears meanwhile corresponding in sizes to the mentioned heating and giving a certain brittleness to the material. For removing of this network with the brittleness resulting due to it, it is necessary to have a second supplementary annealing at a temperature a little above Ac_3.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

THE HARDNESS OF CHROMIUM-NICKEL STEEL DEPENDING OF HEAT TREATMENT. By P. J. Soldau and W. N. Semenoff. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 101.

Chromium-nickel steel (carbon 0.29 per cent; chromium 1.79 per cent; nickel 5.08 per cent; manganese 0.80 per cent) has been systematically studied after hardening and tempering at a different temperature. The minimum Brinell hardness (250) is attained after tempering at 680 degrees Cent. and further quenching in water. In such condition, the steel is easily wrought mechanically. In case of overheating of the steel above 680 degrees Cent., the hardness increases again even after slow cooling. For attaining minimum hardness a new heating is required up to 670-680 degrees Cent. and a further quenching in water.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

THE INFLUENCE OF SPECIAL ADMIXTURES ON THE CRITICAL POINT AND THE STRUCTURE OF STEEL. By M. Z. Nesselstrauss. *Proceedings* of the second Congress of Scientifical Promoters of Metallurgy in Leningrad, May, 1924, 51.

The influence of chromium, manganese and nickel on the position of the point Ac_1 and on the contents of carbon in the pearlite was studied. This influence varies as the contents of the above mentioned admixtures and is expressed by the following figures:

Special Admixtures	Maximum Content of Admixtures in the Studied Steels, Per Cent	Normal Temperature of Ac_1, Deg. Cent.	Influence of 1% of the Admixture on the Position of Ac_1, Deg. Cent.	Influence of 1% of Admixture on the Content of Carbon in Pearlite, Per Cent
Cr	17	820	+6	—0.12
Mn	10	670	—5	—0.25
Ni	15	610	—7.3	—0.03

Tungsten and molybdenum like carbon increase the temperature of the transformation Ac_1; silicon also increases Ac_1, but this occurs on account of the change of the metastable crystallization ($Fe + Fe_3C$) into stable one (Fe + Graphite). The admixtures, decreasing the temperature of the transformation Ac_1, and increasing it, at fixed contents, can render the steel self-hardening: the first act after heating a little over Ac_1, the second only after the heating much above the point Ac_1.

M. Oknoff and G. N. Koulginski, Leningrad, Russia.

POURING INGOTS BY A NEW METHOD. In *Iron Age*, January 14, 1926, page 128.

This article tells of the difficulties that arise in the efforts to secure solid, compact ingots, particularly for alloy and high carbon steels, and shows how these difficulties may be overcome by the use of the reservoir and float multitude-pour method of pouring steel. The reservoir and float are made of fire brick material, and may be used with standard open-top molds or with notch molds. The floats are constructed with four or more holes at the bottom and as far from the center as possible. The steel runs into the molds through these holes. In breaking the descent of the metal the float frees a considerable percentage of gases, keeps the metal from splashing on the side of the mold, and helps make a more solid and compact ingot with greater freedom from cracks and seams. By heating the walls of the float and reservoir while the steel is being poured, the metal last poured into the ingot loses little of its original heat through contact with the walls of the float and reservoir. It is claimed that several indirect savings result from the use of the reservoir and float. Longer life is obtained from stools, buggies and ingot molds. Stool stickers are materially reduced and broken buggy axles rarely occur. The refractory top does not stick to the ingot after stripping, and for this reason little refractory material reaches the soaking pits. It is claimed that by this method of pouring ingots a much better finished material is obtained and a greater yield. There are illustrations of floats, reservoirs, molds and ingots.

Reviews of Recent Patents

By
NELSON LITTELL, Patent Attorney
110 E. 42nd St., New York City
Member of A. S. S. T.

1,569,355, Method of Annealing Sheet Steel, Guerney H. Cole, of Forest Hills Borough, Pennsylvania, Assignor to Westinghouse Electric and Manufacturing Company, a Corporation of Pennsylvania.

This patent describes a method of annealing or rather reannealing silicon steel sheets for use in making transformer cores. In the ordinary manufacture of these sheets, they are first annealed to bring about a molecular rearrangement and then punched or cut to the desired form, after which they are reannealed to remove the strains of the punching or cutting process. Heretofore it had been considered necessary to prevent access of air to reduce oxidation on the sheets being reannealed. This inventor has discovered, however, that a great improvement in the core losses and economy in the reannealing step may be secured by a low temperature anneal, preferably around 700 degrees Cent., without taking any precautions to exclude the air. This process eliminates the expense of air tight annealing boxes for the sheets and the lower temperature results in considerable economy in fuel.

1,569,996, Alloy, James I. Mee, of Hamilton, Ohio.

This patent describes an alloy for producing drill-proof and non-burnable plates for burglar-proof vaults, safes, and the like. The composition of the alloy is 68 per cent tungsten, 2 per cent vanadium, 4 per cent carbon, 2 per cent chromium, 1 per cent sulphur, 5 per cent copper, 3 per cent iridium and 15 per cent pig iron. The alloy is produced by melting the pig iron and bringing it to a temperature of about 2700 degrees Fahr. and adding to the molten pig iron the tungsten, vanadium, carbon, chromium, sulphur and copper and then raising the temperature until these ingredients are practically melted and adding the iridium, which acts as a cleansing agent. The temperature is then raised to approximately 5450 degrees Fahr. and the batch agitated to bring about a thorough incorporation of the ingredients and then poured into molds to form sheet or slab castings. Such an alloy will resist boring by drills and is practically immune to the effects of acetylene or other torches.

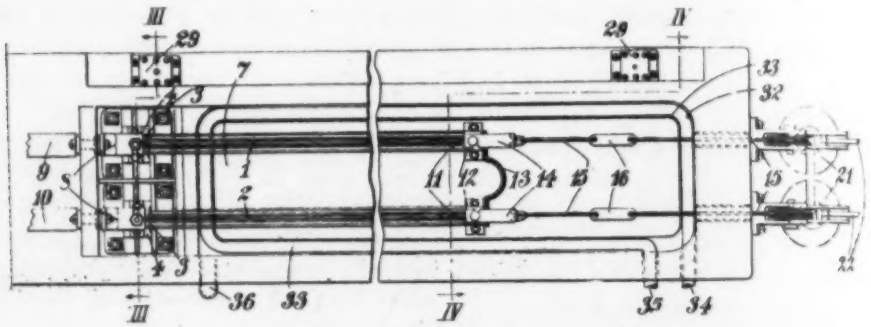
1,570,802, Means for Preventing Adherence of Cast Metal to the Mold, Foord Von Bichowsky, of Glendale, California.

This patent describes a mold coating, particularly for the casting of steel and other high melting point alloys, which are poured near to the melting point of the molding sand so that the burning of the sand to the casting necessitates an expensive cleaning operation. The inventor points out that the use of lampblack or graphite as a mold coating for these

metals is not always permissible because of the absorption of the carbon of the coating into the skin of the casting, producing a brittle skin. The preferred coating, according to the patent, is a substance containing an appreciable quantity of combined nitrogen, such as for example, crude titanium nitride, associated with metallic iron, although the inventor has discovered and claimed the general use of combined nitrogen in the form of a nitride of the carbon group of elements as a mold coating composition.

1,570,815, Process and Apparatus for Insuring the Straightness of Metal Tubes and Strips of Angle or Other Form During Heat Treatment, Hamilton Neil Wylie, of Coventry, England.

This patent describes an apparatus for insuring the straightness of tubular or strip articles undergoing heat treatment. The apparatus comprises a muffle type furnace 7, shown in plain view on the figure, having



fixed clamps 4 at one end thereof, connected to electric conduits 9 and 10. The articles undergoing heat treatment 1 and 2 are clamped at one end in the clamps 4 and at the other end in separate clamps 12, clamps 12 being connected by means of a conductor or bus bar 13, which completes the electrical circuit. Cables 15 are secured to the end of the clamps 12 and extend through the end wall of the furnace over suitable pulleys and have weights 21 secured to the ends thereof to place the cables under tension. A suitable cover is placed over the top of the furnace and when the current is passed through the conductors 9 and 10, the materials 1 and 2 are heated, and due to the tension on the cables 15 are elongated or straightened, depending upon the degree of heat and the size of the weights 21. If elongation is permitted, suitable lever means 22 are provided to take the weight off the cables 15. When the proper amount of elongation has been reached or at the end of the desired heating period, the current may be shut off and the furnace flooded with a quenching or cooling medium through the pipes 33.

1,571,014, Mold Compound, Charles E. Lehr, of Bethlehem, Pennsylvania, Assignor to Bethlehem Steel Company.

This patent describes a new mold composition, particularly for steel foundry practice where 40 to 60 per cent new sand is compounded with the old sand for each molding operation. The composition described comprises foundry sand one part, comminuted slag four parts and a small per-

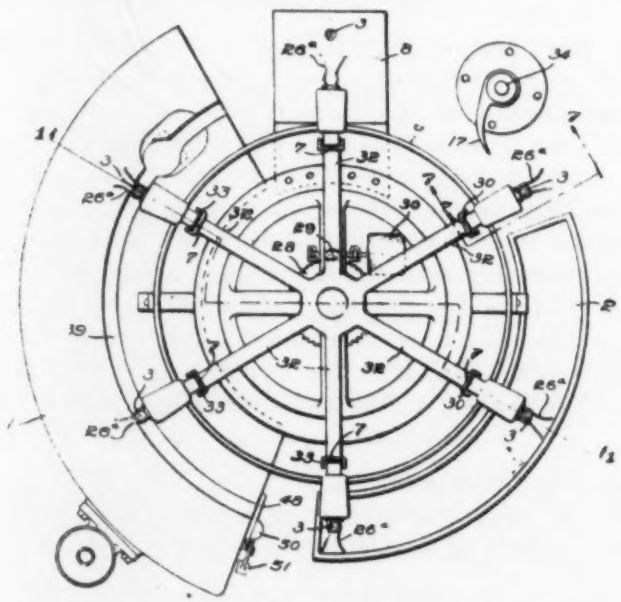
centage of fire clay. This mixture has a high degree of permeability to gases and high refractory properties which prevent the material from burning to the castings, and the comminuted slag is much cheaper than ordinary foundry sand.

1,571,084, Composition for Casehardening, William Clyde Bassett, of Long Beach, California.

This patent is an improvement on the inventor's prior patent No. 1,499,285, in which he substitutes sodium bicarbonate for sodium carbonate in the prior patent, and omits the magnesium carbonate from the composition. The casehardening composition disclosed by the present patent comprises preferably 12 parts of hardwood sawdust, 8 parts of charcoal, and 1 part of sodium bicarbonate, the mixture to be free from sulphur. The sodium bicarbonate is preferably mixed with the sawdust and charcoal by preparing a solution of the bicarbonate in water mixing and drying. The composition may be reused many times, it being advisable to add a small amount of fresh composition from time to time during the reusing.

1,571,329, Heat Treating of Articles, George H. Gilman, of Boston, Massachusetts.

This patent describes an apparatus for heat treating metal articles such as, for example, rock drills, which comprises a rotating turret having a plurality of arms 32, each adapted to rotate a supporting block 7 for

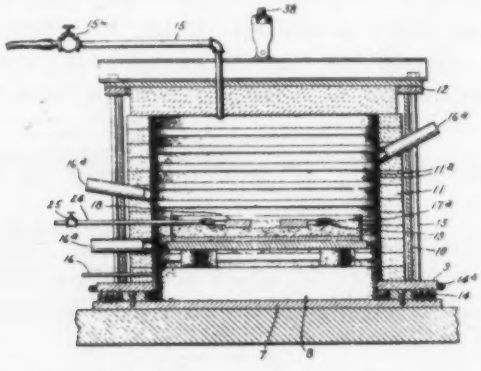


supporting the rock drills 3 by means such as spring clips 26A. Blocks 7 are slidable vertically in the channels 33 at the ends of the arms 32, so as to permit the lowering or raising of the drills 3 as the blocks 7 slide on the cam plate 6. The drills are inserted in the spring clips 26A at the charging platform 8 and thence rotate into the furnace 1, in which they are

subjected to the desired heating from the furnace 1, and thence past the quenching tank 2 where selected portions of the drills are subjected to a progressive quenching action and thence past the drill removing device 17, which is mounted on the standard 34.

1,571,742, Closed Furnace and Method of Operating the Same, Christian Steenstrup, of Schenectady, New York, Assignor to General Electric Company, a Corporation of New York.

The furnace described in this patent comprises a muffle chamber in which the charge 18 is supported from the bottom of the chamber by means of a bed of sand 8. The walls of the chamber comprise a metal cylinder 10 and a cylindrical lining of heat-insulating material 11 which supports the resistors 11A to heat the furnace. A suitable gas, depending upon the



nature of the treatment, is introduced into the furnace through the pipe 15, and a small pipe 16 extending from adjacent the bottom of the furnace permits a small amount of the gas to escape where it may be burned at the end of the tube 16 to indicate the gas conditions of the furnace. Surrounding the charge 18 is an annular cooler tube 19 having a large number of perforations 20 through which a selected cooling gas may be directed to the rim or any selected part of the charge 18, so as to control the temperature of a selected portion of the charge independent of the temperature conditions within the furnace. Sight tubes 16c permit observation of the change. The patent claims as novel a furnace of the type described comprising the means for heating the container and its charge, and means independent of the heating means for controlling a selected portion of the charge.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested To Refer to Serial Numbers of Questions

QUESTION No. 164. In the manufacture of cast iron pipe in a permanent mold, the pipe is removed from the mold at about 1200 degrees Fahr. and then reheated to about 1800 degrees Fahr. for an anneal. Are the structure and physical properties of this material any different from that of cast iron which has been allowed to cool to atmospheric temperature before being reheated to the 1800-degree Fahr. zone? Does anyone know where the practice of removing cast iron at red heat from a mold and reheating for "annealing" was carried out prior to 1918?

QUESTION NO. 163. What is the lowest temperature at which ingot iron or low carbon steel will carburize when packed with the usual type of commercial carburizer?

QUESTION NO. 159. What is the explanation for the retarding effect on corrosion of small amounts of copper in low carbon steel?

QUESTION NO. 158. What is the present recognized cause for the "transverse fissure" as occasionally found in rails?

QUESTION NO. 157. Does 0.070 to 0.090 per cent phosphorus in low carbon basic open hearth steel tend to prevent "stickers" in the rolling of sheets? If so, what is the explanation for such a tendency?

QUESTION NO. 156. What is the cause of "stickers" in the rolling of sheets from low carbon, basic open hearth steel sheet bar?

QUESTION NO. 155. Is it more advisable to cool an ingot from melting temperature down to room temperature before reheating for forging or to cool it down to 1000 degrees Fahr. and then reheat to forging temperature?

QUESTION NO. 154. What are the advantages of nickel steel versus chromium-nickel steel for carburizing?

QUESTION NO. 149. Do plates of basic open hearth steel ever have a higher base rate than acid open hearth steel?

QUESTION NO. 142. *What is the consensus of opinion of the cause of blisters in low and high grade steels sheets?*

QUESTION NO. 138. *Is the electrolytic pickling process being used to show up defects in steel bars? If so, how does it compare with the regular pickling processes?*

DO YOU KNOW?

There is a world of valuable information contained in the A. S. S. T. Handbook and so in an endeavor to emphasis this point, questions will be printed on this page each month. The number and page of the data sheet containing the answer will be given also.

If you are not sure of the answer to all of these queries or even if you are, why not verify it by looking in your handbook. There you will find the answers to these important questions and also you will observe many other important facts that probably you did not realize were in your own A. S. S. T. Handbook.

1. *How is the Sherardizing process carried out?*
   ANSWER: A. S. S. T. Handbook, page A-48.
2. *Is it necessary to preheat stainless steel before forging? If so, what temperature is used?*
   ANSWER: A. S. S. T. Handbook, page D-3.
3. *What is the vanadium content usually used in tool steels, including high speed?*
   ANSWER: A. S. S. T. Handbook, page F-8.
4. *What are the mechanical properties of tungsten steels having a low carbon content?*
   ANSWER: A. S. S. T. Handbook, page I-2.
5. *At what temperature is high speed steel preheated?*
   ANSWER: A. S. S. T. Handbook, page M-3.
6. *What is the normalizing temperature for a plain carbon tool steel having a carbon content of between 0.65 to 0.80?*
   ANSWER: A. S. S. T. Handbook, page N-3.
7. *Who manufactures the high speed steel Supremus?*
   ANSWER: A. S. S. T. Handbook, page N-18.
8. *What proportion of new and old carburizing compound makes a suitable shop mixture?*
   ANSWER: A. S. S. T. Handbook, page R-6.
9. *How is the exfoliation of the case from the core eliminated with carburized parts?*
   ANSWER: A. S. S. T. Handbook, page R-9.
10. *What steels are generally used for carburized gears?*
    ANSWER: A. S. S. T. Handbook, page R-15.
11. *What type of specimen is used for determining the compression strength of steel?*
    ANSWER: A. S. S. T. Handbook, page V-21.
12. *When making coil springs and the coiling operation has been severe, how should the spring be cooled?*
    ANSWER: A. S. S. T. Handbook, page Y-4.

News of the Chapters

STANDING OF THE CHAPTERS

IN the February issue of TRANSACTIONS appeared the relative membership standing of the 29 chapters of the Society as of December 1, 1925, and as of January 1, 1926. The tabulation which appears below shows the relative membership standing of the chapters on January 1, 1926, and February 1, 1926.

Standing as of February 1, 1926

GROUP I	GROUP II	GROUP III
1. Detroit (363)	1. Hartford (126)	1. Tri City (62)
2. Cleveland (362)	2. Lehigh Valley (110)	2. Los Angeles (62)
3. Philadelphia (314)	3. Golden Gate (107)	3. New Haven (57)
4. Pittsburgh (310)	4. Syracuse (95)	4. Rochester (53)
5. Chicago (282)	5. Milwaukee (89)	5. Worcester (53)
6. New York (231)	6. Cincinnati (74)	6. Washington (52)
7. Boston (224)	7. St. Louis (69)	7. Schenectady (50)
	8. Indianapolis (67)	8. Rockford (49)
	9. Buffalo (56)	9. Providence (42)
	10. North-West (49)	10. Toronto (40)
		11. Springfield
		12. South Bend

Standing as of January 1, 1926

GROUP I	GROUP II	GROUP III
1. Detroit (379)	1. Hartford (121)	1. Tri City (64)
2. Cleveland (371)	2. Lehigh Valley (107)	2. Los Angeles (61)
3. Pittsburgh (307)	3. Golden Gate (95)	3. Rochester (60)
4. Philadelphia (293)	4. Syracuse (94)	4. New Haven (58)
5. Chicago (280)	5. Milwaukee (88)	5. Worcester (53)
6. Boston (234)	6. Cincinnati (74)	6. Schenectady (51)
7. New York (230)	7. St. Louis (68)	7. Washington (50)
	8. Indianapolis	8. Rockford (49)
	9. Buffalo	9. Providence
	10. North West	10. Toronto
		11. Springfield
		12. South Bend

For January there was a net gain of 8 members, making a total net gain of 275 new members since September 1, 1925. One hundred and eight new members paid dues during January. However, there was a loss of 75 members dropped for non-payment of dues and 25 resignations, making a total loss of 100 members, leaving a net gain of only 8 for the month.

Boston, Cleveland and Detroit were in competition as to which one would loss the largest number of members. Detroit heads the list with 18, Cleveland 2nd with 10 and Boston 3rd with 9. Some of these losses may be retrieved. However, it is deemed advisable that executive committees should consider at their meetings the names of the individuals dropped for non-payment of dues. This list is available from either the secretary or the chairman, as it is contained on the chapters' monthly report.

GROUP I—Detroit is now one member ahead of Cleveland. This gain of Cleveland on Detroit was not due to any special activity on the part of Cleveland, but more to the fact that Detroit lost more members than did Cleveland.

Congratulations to Philadelphia! They added 27 new members to their rolls; however, they lost a few by resignations and arrears. Nevertheless, their gain was sufficient to place them ahead of Pittsburgh and to go to third position. Chicago's activities are worthy of note, inasmuch as they added 12 new members last month largely through the efforts of their secretary, Arthur G. Henry. This is the largest gain that Chicago has had for a long time. New York had a net gain while Boston suffered a loss, so the positions of New York and Boston have been reversed with New York in 6th and Boston in 7th.

Group II—The chapters in Group II remain in the same relative position as on the last report. Golden Gate had a net gain of 12 new members. This chapter is putting on a course of lectures with over 60 in attendance and a reduced rate is made to those who are members of the Society or become members before the course is completed. In addition, they have forwarded two sustaining memberships at $100.00 each and have the promise of 4 more. Golden Gate will receive $93.50 from each of these sustaining memberships.

Group III—New Haven takes position 3 and Rochester goes to 4. This change was due more to the loss by resignations on the part of Rochester than by membership activity of New Haven. Washington passed from 7th to 6th place. These chapters were close last month and only two members separate them at present. The remaining chapters in Group III are as on the last report.

BOSTON CHAPTER

The February meeting of the Boston Chapter was held at the Gray and Davis Plant of the American Bosch Magneto Company, at Cambridge, on February 5, 1926, through the courtesy of Mr. Howard, factory manager.

The visitation started at 3:00 p. m. and the eighty members and guests were taken through the entire plant, particular interest being shown in the hardening rooms and press equipment.

A turkey supper was served in the shop cafeteria at six o'clock, after which J. H. Bowne, superintendent of the Amesbury Plant, described, with the aid of sketches, the development and heat treatment of the pressed steel parts of the Gray and Davis starter and generator.

At eight o'clock, A. J. Porter, Jr., sales manager of the Heppenstall Forge Company, at Bridgeport, Connecticut, addressed the Chapter on the "Manufacture and Heat Treatment of Die Blocks." Using motion pictures taken at the Heppenstall Forge & Knife Company, Pittsburgh, he described

the melting, casting and forging of die block steel and then proceeded to explain the characteristics and heat treatment of carbon, alloy and heat treated die blocks, stating that in the West, seventy-five per cent of the blocks sold were heat treated by the manufacturer before being machined, while in the East, conditions were just reversed. Mr. Porter then described the effect of poor design, good and bad heat treatment, as well as abuse in the hammer, upon the life of the die and also the benefits which were obtaind by using heat treated shoes in the drop hammer.

A lengthy discussion followed the presentation of the talk, the principle topics being the methods of quenching and tempering water hardening and oil hardening drop hammer dies. Mr. Porter's paper was well received and he was given an enthusiastic vote of thanks.

The severity of the previous day's snow storm made it impossible for the chairman to be present. The meeting was presided over by the Secretary, the program being under the general direction of H. B. Parker.

H. E. Handy.

CHICAGO CHAPTER

February 11—A Practical Talk on Alloy Steels (Illus.). Marcus A. Grossmann, metallurgical Engineer United Alloys Steel Corp., Canton, Ohio. Graduate M. I. T.; formerly with Pittsburgh Testing Laboratories, American Vanadium Co., U. S. Bureau of Standards, Vanadium Corp. of America, Electric Alloy Steel Corp., Atlas Steel Corp.

Considerable international color and atmosphere was lent this meeting by the presence at the speakers' table of Mr. Lomax, British Vice-Consul at Chicago, and J. Leslie G. Davies, assistant to the president of Baldwins, Ltd., England. These gentlemen responded to the introduction with a few words on their impressions of American industry in comparison with industry in England. Mr. Davies further made the statement that he would gladly do anything he could to further the interests of the Society in England. Mr. Hyman Bornstein, National Director, was also present, and addressed the meeting.

The Chicago Chapter as time goes on is apparently concerning itself more and more with problems in the making of steel, whereas heretofore almost the entire yearly program was concerned with the subsequent treatment of the steel. This marks an important and interesting tendency in the expansion of the society itself and has been noted throughout the entire national organization. This is naturally reflected by the class of the attendance professionally and this month's meeting, which by the way was the largest in attendance of the year, saw the presence of men who are interested in steel purely from a manufacturing standpoint.

Mr. Grossmann's lecture on the practice of making alloy steels as carried out in this country was extremely important and different from other lectures we have heard on similar subjects in that his chief concern was obviously to stress the technical reasons underlying these practices. After one had heard his talk and the extended discussion following it, one obtained the greater impression of just how subject steel making is to certain orthodox, immutable laws. Certainly if we knew and understood all the laws that applied

in any case we would be more positive and standardized in our practices. It was this fact that Mr. Grossmann endeavored to drive home.

J. A. Comstock.

CLEVELAND CHAPTER

A talk on "Stainless Iron and Steels," by T. Holland Nelson, was the feature of the February meeting of Cleveland Chapter. This meeting, which was held in the ball-room of Hotel Winton on February 19, at 8:00 p. m., was fairly well attended, but would undoubtedly have been much better attended had the absent members realized that an unusually good presentation of this subject was to be on the program.

Mr. Nelson is not only a master of his subject, but has in addition the ability to present his facts and theories in an interesting and entertaining manner. In other words, he lived up to the advance announcement made by the program committee.

The speaker gave first the history of stainless steel and stated that its invention was in reality accidental. The iron-chromium alloy which later developed into stainless steel was first made as an alloy intended for an erosion-resisting gun-lining. Several alloys were manufactured and tested for this purpose before the discovery came that some of them were also unusually resistant to corrosion, that is, "stainless." Since that time a large number of different analyses have been tried, but all stainless steels can at present be roughly divided into three general classes or types, first the 12-14 per cent chromium type, second the 16-18 per cent chromium with 1 per cent silicon type, and third the nickel-chromium-iron alloys.

According to the speaker, each one of these types has its own field of usefulness. The selection of the right alloy depends to a great extent on what the user expects from the steel. If malleability is important, for instance, the second type would be superior, but if resistance to acid corrosion is of chief importance, the third type might be best. Generalizations here are dangerous. In making a selection, the advice of a metallurgist thoroughly familiar with all types is to be desired.

Mr. Nelson stated that the stainless steels from one point of view are very simple. Their corrosion-resistant properties are explained by the fact that the chromium and iron unite to form an alloy insoluble in water and many other liquids. By producing this "insoluble" alloy we get a steel that cannot rust. At present chromium is the only comparatively cheap element available for alloying with iron which will form the insoluble compound.

The processes for the manufacture of stainless steels and the difficulties encountered in manufacture were discussed and illustrated by lantern slides. A number of questions on these points were also answered by the speaker during the discussion period.

Mr. Nelson is an enthusiast on the subject of stainless steels and believes we are just beginning to make use of them. Their further development and their use for many new purposes will bring about a revolution."

About 25 members and guests attended the dinner which preceded this meeting.

A. S. Townsend.

DETROIT CHAPTER

The February meeting of the Detroit Chapter of the American Society for Steel Treating was held Monday, February 15, in the General Motors Building. The usual Coffee Talk was given by F. E. Searles, head of the Ford Trade School. The Ford schools will take in boys of 12 years of age. They are given one week academic work and two weeks in the school shop until 18 years old. They are paid $7.20 and $18.00 per week plus $2.00 per month thrift money and a hot noon lunch. The usual class subjects are taught with, however, little attention to cultural subjects. At the completion of the course the student has completed 3 years of high school. The students are picked as much as possible from those whose life has given but little opportunity. At present there are 720 enrolled with a waiting list of 4,000.

Men from 18 to 30 years of age can enter the Ford Apprentice School and learn a trade. At present there are 1300 such students enrolled on a 3-year course. Their rate is from $6.00 to $7.60 a day.

There are two other Ford educational projects; (1) Ford Service School. A two-year course to train men for the company's service largely in the foreign field. These men are placed in various manufacturing and assembly departments to learn the business. Instructors follow the work of these students, check them on the job, and make sure they are given an opportunity to master the work in each department. In this course there are 450 enrolled at a rate of $6.00 a day. (2) The second and last Ford educational project is designed to take care of special students. Classes are held in (1) Metallurgy, (2) Metallography, (3) Electricity, (4) Mech. Drawing, (5) Mathematics.

An idea of the size of the total project may be gathered from the following: Students in classes 3,200, full time instructors 70.

The first speaker of the evening was Walter G. Hildorf of the Reo Motor Car Company, who spoke on "Normal Steel, Fracture Testing and Grain Size."

Mr. Hildorf asked that his paper be considered in the latter part as a progress report rather than a finished one. The object of the investigations was to do away with the variables that occur in automobile parts. Steels were divided into normal and abnormal classifications as follows; (1) A normal steel is a steel that will harden 100 per cent when heat treated in the regular way. (2) Abnormal steel is prone to soft spots, variation of case and core when carburized and will average only ⅔ the depth of a normal steel. Slides illustrating these features were shown.

Discussing warpage, Mr. Hildorf finds that abnormal steel warps much more than normal and has no special direction of warpage. Curves showing heating and cooling of steel through the critical range were used to explain this warpage.

Fracture testing has been well developed by Mr. Hildorf. His procedure is as follows in specimens of axle shaft diameter:

Heat to 1550 degrees Fahr. hold 1½ hours, cool in air.

Heat to 1425 degrees Fahr., then furnace cool.

Piece is taken, sawed ⅛ the way across and slowly broken in a press.

The fractures are: (1) Silky fibrous, (2) Crystalline fracture, (3) Reedy fracture, (4) Flaky. From these fractures an excellent idea of the properties, especially fatigue, is gained.

Fracture No. 1 is desired. No. 2 is dangerous and can not be removed by heat treatment so that upon giving the treatment outlined above it will return crystalline. This steel machines harder than the others and has a very poor Izod test. No. 3, the reedy fracture is due to (1) dirt, (2) non-metallic inclusions, and (3) segregations in the steel as for example, of ferrite. Tests by Michigan State College on impact values of heat treated bars made from steels sorted as outlined gave the impact values highest for silky fibrous steel. This work has been published and curves from these tests were shown.

Due to the variations in grain size in normal and abnormal steels it became evident that a standard for grain size was essential. A chart of 10 sizes has been made by Mr. Deuble of United Alloy Steel Corporation. This chart was shown by means of slides. Mr. Hildorf tests grain size by carburizing 1700 to 1800 degrees Fahr. for 8 hours and cool in the box. The grain size is compared with the standard. It seems to be proven that no matter what the previous thermal treatment the steel if treated as outlined will return to its original grain prize. Prof. Publow of Michigan State College tested this by heating a piece of S.A.E. 1015 at 1700 degrees Fahr. for 36 hours and cooled very slowly. The grains were enormous. When the sample was treated as Mr. Hildorf outlined it returned to its original grain size and could not be told from another piece of the same bar similarly treated. Forging and other treatments only served to emphasize this general law. We then now know that regardless of what we do with it we cannot change its grain size and keep it the same as other bars that for some reason or other seem to have a different grain size. There is a controlling factor in mill practice of which as yet we have no definite knowledge. Mr. Hildorf felt sure that since we get better properties with a smaller grain size it is up to the steel mills to produce it, and he felt deeply the need of more investigations by metallurgists. The Reo Motor Car Co. would be glad to co-operate with any who felt interested.

At this point Mr. Deuble of the United Alloy Steel Co. took up the talk from the producer's side.

Mr. Deuble explained how the large and small grained steels were brought to their attention. Upon investigation they decided to use 1850 degrees Fahr. carburize heat for 4 hours. Upon this work the grain size chart shown by Mr. Hildorf was made. The work was then extended to test variations through a heat. In most cases the bar grain size and billet grain size checked. Going back to ladle sample results pointed to the fact that the grain size of the bar could be predicated.

Exhaustive tests showed the possibility of using the grain size table by different operators and checking within two numbers. This points to the eventual adoption of standards. Mr. Deuble closed by saying that

this work means close co-operation between metallurgists of both the producers and consumers.

The discussion was turned over to Howard Stagg who gave an interesting account of his work and ably commented on Mr. Hildorf's curves and micrographs. General questions followed and at the close of the meeting a rising vote of thanks ended one of the best and largest meetings of the Detroit Chapter for 1925-1926. *F. P. Zimmerli.*

GOLDEN GATE CHAPTER

The fifteen weeks' course in "Practical Metallurgy for Steel Treaters" being sponsored by the Golden Gate Chapter is now well under way. The first meeting was held on January 11. The course consists of lectures, demonstrations and laboratory work so arranged that the various processes of steel making and steel treating will be explained and worked out in sequence. This method of teaching gives to those taking the course both the theoretical and practical knowledge necessary for good workmanship. More than 60 are attending this course.

The various subjects pertaining to the making and heat treating of steel which are to be considered in this course are:

Subjects	Instructors
Steel Making	W. J. Crook
The Mechanical Treatment of Steel	Four men prominent in industry
The Chemical Constituents of Steel	H. S. Taylor
The Iron-Carbon Diagram	W. J. Crook
The Microscope	H. S. Taylor
Pyrometry	H. E. Morse
Heat Treating Equipment	S. H. Edwards
Annealing and Normalizing	E. H. Kottnauer
Hardening and Drawing	S. H. Edwards
Carburizing and Cyanide Hardening	C. S. Moody
Special Methods of Hardening	E. H. Kottnauer
Alloy Tool and High Speed Steels	E. H. Kottnauer
Common Defects in Steel	E. H. Kottnauer
Testing Steel	R. E. Davis
Inspection	H. S. Taylor

This course is another indication of the many ways in which the A. S. S. T. and its chapters is being of great service to its members, and we are sure that the results of this particular effort of the Golden Gate Chapter will be far reaching.

HARTFORD CHAPTER

Mr. Sam Tour, metallurgist of the Doehler Die Casting Co., addressed the Hartford Chapter on "The Die Casting Process" on the evening of December 8, 1925, at the Hartford Engineers Club. Although all the materials which are die-cast are non-ferrous metals, nevertheless the process and particularly the die equipment are of interest to heat-treaters.

Mr. Tour showed by means of lantern slides the development of die-

casting machines and the limitations and possibilities of each type. He also showed how by the use of alloy steels the die life had been considerably lengthened.

The audience was quite amazed at statements concerning the size and weight of the dies required for producing what appeared as simple castings.

The speaker had on display many examples of intricate as well as simple die castings.

On January 12, 1926, the Hartford Chapter listened to a talk on "The Relation of Tool Steels and the Tool Room," by Mr. A. H. Kingsbury of the Crucible Steel Co. His talk dealt principally with alloy tool steels and he made the statement that in the near future all tool steels will be either of the alloy or high speed type.

Mr. Kingsbury gave a classification of all the alloy tool steels, the limits of composition, and the uses for which each class was particularly adapted.

As is usual at Hartford meetings, when a tool steel subject is brought up, a lively discussion follows:

The February meeting of the Hartford Chapter was held on Tuesday, Feb. 9, 1926, in the rooms of the Hartford Engineers Club. Preceding this meeting the executive committee met during the afternoon and at dinner with National President R. M. Bird and Secretary W. H. Eisenman to discuss the policies of the National Society, particularly those relating to the Hartford Chapter.

The speaker of the evening was F. C. Langenberg, metallurgist of the Watertown Arsenal, whose subject was "Cold Working of Forgings." This paper was published in the October, 1925, issue of TRANSACTIONS and describes the method and benefits resulting from cold working hollow cylinders such as a gun tube by means of an hydraulic pressure of approximately 150,000 lb. per square inch applied to the inside of the tube, while the outside is confined so as to expand only about 5 per cent. The method results in a considerable saving in the manufacture of large guns and also allows the use of a higher powder pressure for the same size gun over that allowable by the usual compound construction. A large part of the development of this process involved means of producing and retaining the extremely high liquid pressures required. The same equipment can be used in many other industries, and Dr. Langenberg predicted that high pressures would soon be used in many fields, particularly in the chemical industry.

Plans are now well under way for the Spring Sectional Meeting to be held in Hartford, May 20 and 21, 1926, and it is confidently expected that this will be the most successful Sectional Meeting ever held by the Society.

INDIANAPOLIS CHAPTER

On Monday evening, February 8, more than 125 members and guests enjoyed a chicken dinner and musical entertainment preceding the monthly meeting of the local chapter, when J. M. Watson, chief metallurgist for The Hupp Motor Car Company of Detroit, gave a most interesting and instructive illustrated lecture on "Manufacture and Heat Treatment of

Automobile Parts.'' More than 80 more men who were unable to attend the dinner program arrived in due time to hear the addresses of the evening.

G. M. Williams, president of The Marmon Automobile Co., of this city, gave a most interesting talk regarding the manufacture of automibiles and cited the real necessity of employing the most modern and efficient methods in order to survive the great struggle for existence of the automobile companies, emphasizing that ''lazy'' materials are just as much an expense as ''lazy'' men. He also outlined the natural advantages which place Indianapolis in a position of leadership in the industrial world in the future, stating that this is one of the few cities where it is not necessary to print shop signs in four languages or more. The workmen in this district are living under better conditions and are generally satisfied, which means a great reduction in the annual turnover of labor. Just as the automobile plant has been compelled to forget the ''rule and thumb'' method in manufacturing so the ''heat treater'' has to forget the same rules and must rely upon science in order that he can develop into a man whose services will be sought by the employer.

Mr. Watson outlined the methods of heat treating parts and contrasted old motor car designs with the newer ones which have been made possible by the use of alloy steels and more scientific treatment of all steels which make up the car. He also mentioned the desirable results which he has noted in heat treating steel castings, and predicted great progress in the future. The talk was well illustrated by moving pictures, and every man left with a better conception of the advantages of modern methods of heat treatment. Much credit for this progress was given to The American Society for Steel Treating.

As evidenced by the large attendance at recent meetings, considerable enthusiasm has been developed and the Indianapolis chapter is hoping to increase its membership in the near future.

The musical program was furnished by R. O. Fristoe, and W. P. Durbin who have a record of not missing a single meeting this year.

Our next meeting will be held Monday, March 22, at the Y. M. C. A. auditorium, and arrangements have been made for broadcasting over WFBM (268 meters) the musical program as well as short addresses by our National President R. M. Bird, by Wm. H. Eisenman, National Secretary, and by Dick Miller, president of The City Trust Company, this city, and W. G. Praed, chairman of the local chapter.

Tune in on WFBM (268 meters) Indianapolis, and if you enjoyed the program we would appreciate receiving your comments.

C. H. Beach.

LOS ANGELES CHAPTER

The January meeting of the Los Angeles Chapter was held January 7, 1926, in the club rooms of the Los Angeles Creamery Company. Dinner was served preceding the meeting, the diners being entertained with songs and music by members of the Axelson Machine Co. staff.

William Graw, production superintendent of the Union Tool Co., Torrance, California, speaker of the evening, presented a paper entitled "Tool Grinding," his subject covering a great many interesting points in grinding equipment and grinding methods. Mr. Graw has made extensive investigations along this line of work and his paper was exceedingly interesting. The speaker with the aid of his assistants arranged an exhibit of charts, tools and grinding wheels which was very interesting. A general discussion followed the speaker's remarks.

The February meeting of the Chapter was held February 4 in the Conference room of the Westinghouse Electric & Mfg. Co.

The speaker on this occasion, Max Lee, in charge of the city sales in the industrial department of the Westinghouse Electric and Manufacturing Co., chose for his subject, "The Costs of Heat Treating." Mr. Lee's paper proved to be very interesting, bringing out very clearly and in a concise manner the "fixed charges" together with the costs of operation of the oil, gas and electric type furnaces for the various operations of treatment. Mr. Lee has had considerable experience in compiling data of this character and his subject proved to be one of great interest. *E. C. Black.*

NEW HAVEN CHAPTER

The regular monthly meeting of the New Haven chapter was held on February 19 in the Winchester Clubhouse. We entertained Mr. G. L. Reichhelm, Socony Burner Corp., New York, N. Y. (Industrial Division).

Mr. Reichhelm delivered an impressive and thoughtful talk on combustion. Taking as his text a simple definition of combustion, he showed the analogy of combustion in our bodies, in nature, and in industrial applications. All combustion is attended by heat, although in some of the slower forms of combustion it may not be apparent to our senses. Fuel combustion, as utilized in the industries, is not very efficient. From an ideal standpoint, fuel should be burned with a blue gas, or non-luminous flame. While this flame develops the greatest amount of sensible heat, it has very little radiating power, and the heat rays must be converted to light rays, in order to obtain radiating value.

As an example of the heat transmitting power of light rays, he cited the sun's rays which travel millions of miles before reaching the earth. These rays may have to penetrate a coating of ice upon our windows, nevertheless, when they inpinge upon an opaque body within the room they register a temperature higher than that of the media through which they have passed.

The Welsbach burner, or mantle, was given as an example of the conversion of the heat rays of a blue flame into light rays of heat transmitting qualities.

He alluded very briefly, in fact too briefly, to the "gasifier" in which oil fuel is atomized, gasified, burned as a blue flame gas, in a heating chamber where the heat is largely converted into radiant form.

It was stimulating to listen to such an able exposition of the fundamental principles underlying the generation of heat.

Unfortunately the inclement weather prevented a large attendance. There were about forty present.

The noticeable fact in connection with the attendance was the absence of New Haven members, and the presence of members and guests from the outlying towns. Practically all the suburban towns except Hartford were represented.

All the leading citizens of Branford were at the meeting. Wait! We will qualify that statement. Forest L. Hammer was not present. If he does not show up pretty soon at the meetings we will have to call on him. How else can we make his acquaintance.

Mr. Burhoe and a friend, both from the Seymour Mfg. Co. negotiated the trip from Seymour. We have not learned if they succeeded in returning home.

Mr. Stegeman, Locke Steel Chain Co., Bridgeport, was with us. He came for information and got it. Mr. Stegeman has been reading about martensite in the January TRANSACTIONS. We wanted to ask him what in the deuce it was, but held back for fear he would flash a Greek dictionary on us.

We hope this reaches the eyes of Mr. Chamberlain and Mr. Fox of The New Haven Clock Co. We spotted them in the audience. Their first visit, we think. (Membership Committee please take note.)

The secretary led a brigade from Wallingford. Whether or not he used chloroform we do not know, but they came.

Two gentlemen from Meriden were among those present.

Mr. Duley, Colonial Steel Co., won the attendance prize. From the shape of the package we should judge that it was a box of cigars. He deserves a box of cigars, two boxes in fact.

We want to get New Haven into the Second Division, Membership column. Give us more support, fellows. Your principal dividend on your membership fee is obtained from these meetings.

Walter G. Aurand.

NEW YORK CHAPTER

The New York Chapter of the American Society for Steel Treating held its January meeting January 27, in the Merchants' Association assembly rooms, Woolworth Building, New York. Mr. F. E. Schmitt, associate editor, Engineering News-Record, New York, adressed the chapter on the subject "Selecting Materials for Service."

Mr. Schmitt brought to attention the question as to whether the present methods of conventional testing actually give results upon which engineers may base the use of materials in engineering design. The point was made that serviceability tests are necessary and desirable in determining the qualifications of materials for service. The testing of steel rails was noted as an example of serviceability testing. In this connection the speaker questioned the value of conventional tests, as described in specifications for rail steel in determining whether rails made from such steel will prove satisfactory in service. The continual changing of conditions, traffic, speeds, weights, etc., during the period of service of a lot of rails, render the interpretation of the statistics difficult. "It may be predicted that no marked improvement in rail quality is likely to be attained until

service tests are developed and applied—always excepting the possibility of some chance innovation of revolutionary kind."

The speaker pointed out that in recent years the variety of materials and new applications of utilization has increased remarkably. The testing art must keep pace with this increase and the speaker questioned as to whether it had done so. The failure of the art of conventional testing to meet the requirements in the case of the application of duralumin to use in the "Shenandoah" was noted as an example.

The meeting was well attended and a lively discussion followed the meeting. *W. E. Griffith.*

NORTHWEST CHAPTER

The February meeting of the Northwest Chapter was held on Wednesday evening, February 24. Three of our members, Mr. Briggs, Mr. Loberg and Mr. Zima, gave a very complete discussion of steel castings industry.

Mr. Briggs, metallurgist of the Minneapolis Electric Steel Castings Company, discussed the various types of furnaces used for melting steel as well as the linings, giving the advantages and disadvantages. He then took up the difficulties confronting the foundrymen such as prevention of blowholes, excessive shrinkage and impurities in steel. The way in which good molding sand aids to overcome blowholes was very clearly illustrated. Great stress was also placed on the design of castings which may often cause a great deal of grief.

Mr. Loberg, superintendent of Foundry of the American Hoist and Derrick Co., discussed the Tropena converter, a modification of the Bessemer type, which is used in their plant. He gave the history of the Bessemer process and its importance to the steel industry. He then described the chemical reactions which take place and the effect they have on the flame at the mouth of the converter. The method of adding the alloys and getting the steel in condition to pour was given in detail.

Mr. Zima, chemist and metallurgist of the Western Crucible Steel Castings Company, discussed the heat treatment of steel castings and emphasized the fact that good steel is necessary in order to bring out good qualities on heat treatment. He also explained the reactions that take place during heat treatment, giving very good illustrations which made it easier to understand just what was taking place in the steel. He then took up in detail the reasons for heat treating castings and the various methods used.

According to the comments after the meeting, everybody enjoyed the program immensely. It might be well to give some more of our local members a chance to tell us what they are doing and how they are solving the problems in their field of work. *L. J. Weber.*

PHILADELPHIA CHAPTER

The fifth regular meeting of the year was held at the Engineers' Club on January 29, 1926.

The meeting was called to order by vice chairman Wiedemann in the absence of Chairman Collins. Mr. Wiedemann promptly turned the meeting over to our National President R. M. Bird, who was the chapter's

guest of the evening. It is always a pleasure to listen to President Bird, and his remarks to the members that evening on the national situation, his ideas and hopes for the future of the Society, were most constructive and helpful.

Dr. H. T. Chandler, of the Vanadium Corporation of America, came to Philadelphia from a sickbed in New York to read a paper to the chapter on Applied Metallurgy and Alloy Steels, but, unfortunately, Dr. Chandler's physical condition prevented the presentation of the paper. The members of the chapter, however, thank Dr. Chandler for the effort he made to come to Philadelphia, and they know they missed a rare treat in missing his paper.

A. E. Donovan.

PITTSBURGH CHAPTER

The Pittsburgh Chapter held its February meeting on the evening of February 4 in the U. S. Bureau of Mines Building.

Quite a few members brought invited guests to the supper which was served at 6:30 p. m. in the cafeteria. During the supper an excellent program of singing and dancing was rendered by six juvenile entertainers.

The meeting was called to order by chairman O. B. McMillen in the auditorium at eight o'clock, and, after a short business session, he welcomed the speaker of the evening, T. D. Lynch of the Westinghouse Electric and Manufacturing Company, who is a past national president of our society. An unusually large crowd turned out to hear Mr. Lynch whose experience and ability so well equip him to discuss and advise upon specifications and requirements.

Mr. Lynch introduced his subject, "Specifications of Materials and Materials in Design," by saying that it was an old story, but one which has grown more and more complex and important, and to impress its importance upon his listeners, he reminded them that there were about 200 organizations whose purpose was to draw up specifications and standards, one of the best known of which is the American Society for Testing Materials. The efforts of some of these organizations are not alone confined within national limits, but are of international scope.

Then he touched upon the benefits gained from research and the increasing importance that it is playing in development. In speaking of the personnel for research work, he said that, for the most part, he found that purely technical research required a different type of mind from that of applied research.

In selecting the specifications of materials used in the electrical industry as examples, he said that he thought its requirements were more diversified and required closer attention than many of the other industries. Pictures of specifications and cards as used by the Westinghouse Electric and Manufacturing Company were shown on the screen while he described the necessity and usefulness of the information they contained.

At this point he digressed to say that those opposed to specifications claim that buying upon specification adds to the cost, but the speaker said that he had found that specifications brought about an equity in competition and made

known to the supplier just what his material must do or what service it must meet.

Following this, pictures were shown of the various metallurgical test specimens and the machines or instruments in or with which the specimens were tested. Mr. Lynch explained all these together with the significance of the results obtained. He also showed how and why test results should be coordinated. In testing material from large castings, he recommended that the test specimens be taken from the body of the casting and not from a test coupon, thus insuring proper grain refinement.

He then gave a number of illustrations of failures of castings and forgings, and explained the reasons for failure. Among these were an example of Stead's brittleness in low carbon steel caused by annealing too long at a temperature between the Ac_1 and Ar_1 points, and another, the fracture of a pinion gear parallel with the keyway but at some distance from it. The explanation of this failure was that while the metal surrounding the keyway was in tension, the remainder was in compression and that failure occurred where these two stresses met. And, in connection with these studies of stresses, Mr. Lynch told of the large amount of time, money and effort that his company had expended in determining the possible stresses and where and how they might concentrate in such large sections as the big motor rotors which they manufacture.

In closing, Mr. Lynch reminded his audience that standard specifications must be kept on a commercial basis as a result of compromise between producer and consumer and that special materials tested in direction of maximum stress are necessary where stresses are abnormally high.

Following this address, many questions were asked and considerable discussion aroused especially as to the proper location on big castings from which test specimens should be taken. *Harry A. Neeb, Jr.*

ROCHESTER CHAPTER

On Monday evening, February 8, the Rochester Chapter of the American Society for Steel Treating held its monthly meeting. A joint meeting with the Rochester purchasing agents was the cause of a large crowd.

After the dinner and a short business meeting, the speaker, T. D. Lynch, of the Westinghouse Electric Company, was introduced. Mr. Lynch chose as his subject, "Specification of Materials and their Application in Design."

The Rochester Chapter found Mr. Lynch a very convincing speaker, and thoroughly enjoyed his talk. *C. F. Wattel.*

ROCKFORD CHAPTER

The February meeting of the Rockford Chapter was called to order in the Nelson House at 8 p. m., Tuesday, the 16th, by Chairman Hillman after the usual supper. The business meeting was quite short and at its close, Mr. Muehlemeyer, chairman of the program committee, introduced F. L. Sage, Refractory Engineer of the Laclede-Christy Clay Products Company, as the speaker of the evening.

The subject of Mr. Sage's paper was "The Purchasing and Testing of Refactories," and was to be accompanied by a moving picture. The

films failed to arrive, however, so Mr. Sage went ahead with a very instructive talk on refractories. Mr. Sage said that, to a great extent, fire brick are purchased on a cost basis and not a service basis today, because of lack of co-operation between the purchasing agent and the man who used the bricks. He explained the great number of variables that influence the quality and nature of a finished brick and gave many reasons for good brick failing under the tests in the factories. Further, he cited the wide discrepancies between laboratory tests and service tests and strongly recommended that the tests be conducted in service not with a few brick but with a whole furnace lining. This he said, was the only way to observe the reaction of the refractory under all conditions of atmosphere, time, temperature and load and their numerous combinations.

As a step in the direction of cutting the refractory costs, Mr. Sage urged what he called "Purchasing Confidence," i. e. that the buyer tell the salesman all his furnace conditions and have enough confidence in the company represented by the salesman to accept its advice as to what quality and kind of bricks to use. Another way to reduce costs is to call in a competent refractory engineer to study the many furnace conditions and make recommendations accordingly. The third way is for the firm to employ a refractory engineer permanently, a man who understands fire bricks and furnaces and let him be responsible for all the refactories.

Although handicapped by the non-appearance of the film, Mr. Sage gave a very interesting and instructive talk, and at its close answered all questions gladly.

SPRINGFIELD CHAPTER

The Springfield Chapter of the American Society for Steel Treating held a meeting on January 19 in the rooms of the Springfield Chamber of Commerce. The usual get-together dinner at the Highland Hotel preceded the meeting. The speaker of the evening was J. P. Gill, metallurgist of the Vanadium Alloys Steel Company, Latrobe, Pa. Mr. Gill who is the co-author of a very interesting paper on the chemical composition of tool steel which recently appeared in the TRANSACTIONS of the Society selected for his talk a subject with which he is thoroughly familiar—the manufacture and heat treatment of high speed and tool steels. The appropriate selection of the subject and its clear presentation assured a very interesting evening for the Chapter members and their guests.

The high speed steel has an interesting history. It is rather remarkable that this steel so essential for the successful development of industrial progress was not destined to be discovered until the second part of the 19th century. The appearance of Mushet steel in 1868 containing tungsten marked the beginning of high speed steel. However, the practical application of high speed steel and its enormous popularity are due mainly to the famous experiments of Taylor and White, known to every mechanic and steel treater. No radical or startling discoveries were made during the last several years, the concentrated efforts of tool steel manufacturers being directed to better understanding of properties of high speed steels and their application to various classes of work.

Mr. Gill gave a general description of the various manufacturing processes for making tool and high speed steels. He divided all high-grade steels according to their chemical composition and their uses into the following groups:

(1)—Carbon tool steels
(2)—Alloy tool steels
  a Water hardening
  b Oil hardening
  c Hard working die steels
  d Finishing steels
(3)—Special alloy steels. (Not used as tool steel.)
  a Non-corrosive steels
  b Valve steels
  c Magnet steels
  d Non-magnetic steels
(4)—High-speed steels

With reference to the ordinary carbon tool steel, Mr. Gill pointed out the importance of the proper classification of the various grades of tool steels with regard to their carbon content. According to the old confusing practice, the carbon content of tool steel was not mentioned directly or indirectly and the tool steels were known according to their application in trade. Today tool steel manufacturers realize the importance of proper classification and in the majority of cases adopted a system which calls for ten temper numbers, each number representing the range of carbon content equal to 0.10 of 1.00 per cent.

The alloy steels and their composition and heat treatment are worked out to suit certain conditions of work. Such steels as finishing steel, non-deforming steels, steels suitable for heading dies, etc., are generally known in every machine shop.

The speaker gave the typical compositions for each important grade of alloy tool steel which he considered as the most successful in performance.

The third group of special alloy steels represents steels which are not used for making tools, but employed in machine construction work. They all have some striking properties which make them extremely valuable for certain uses. The corrosion resisting steel can be cited as a typical example of these steels. This steel, according to the speaker, gives the best service when used in highly polished and hardened condition. A rough surface or scale will usually lead to electrolytic corrosion.

The most popular grade of high-speed steel is that containing about 18 per cent of tungsten. It was estimated by Mr. Gill that 95 per cent of high speed tools are made of this particular grade of material. The usual constituents of high speed steel, such as tungsten, chromium, vanadium and cobalt and their effects on the high speed steel were explained in detail by the speaker. At the conclusion of his talk Mr. Gill answered many questions brought up by the various members of the Chapter. Mr. Oliver, the local chairman, presided at the meeting.

On February 10 the officers of the Springfield Chapter entertained as

their guests R. M. Bird, the National President of the Society, and W. H. Eisenman, the National Secretary of the Society. A dinner was served in the Highland Hotel which was followed by an informal meeting at which the officers of the local chapter and the members of the executive board were present. At the meeting, matters pertaining to the activities and policies of the National Organization and the local Chapter and their mutual relations were discussed. The officers and members of the executive board of the local chapter were pleased to meet their new president and greet Mr. Eisenman who has made many friends among the members of the local Chapter.

N. A. Glaskowsky.

ST. LOUIS CHAPTER

The February meeting of the St. Louis Chapter was held at the American-Annex Hotel on the evening of the 19th.

Again we have to report our largest attendance in years when fully two hundred members and guests gathered to hear George A. Richardson, manager, technical publicity department, Bethlehem Steel Company, Bethlehem, Pa. His address was entitled "The Manufacture of Tool and Alloy Steel." Five reels of new moving pictures were shown, which were taken under the direction of Mr. Richardson. We were pleased to hear that we were seeing the first public showing of these fine pictures.

Mr. Richardson explained the plan of the pictures, and the difficulties encountered in taking mill pictures. The pictures seemed to include every operation in the making of tool steel: showing the laboratory, furnaces, teeming, hammering, rolling, and final inspection. Tools were shown being tested in their own plant. Every one appreciated how well the pictures were worked out, how splendidly taken, and how even more splendidly described by Mr. Richardson.

After these five reels Mr. Richardson gave the chapter an additional treat by showing a reel of pictures from another division of this large plant. This showed some of the more striking and spectacular sights in the plant: large forgings for stills, heavy plate rolling, the flanging of large boiler ends. Every one admired the fine spirit shown by Mr. Richardson in giving such a fine entertainment and in actually doing everything possible to make a successful evening.

Alan Jackman.

SYRACUSE CHAPTER

Professor H. F. Moore of the University of Illinois addressed the Syracuse Chapter of the American Society for Steel Treating at its regular monthly meeting on February 15, the subject being "What Happens When Metals Fail by Fatigue."

Fatigue was defined as the cause of fracture under repeated stresses, the fractures usually showing no elongation. The phenomenon was first seriously studied by Wöhler in about 1860, and the design of the testing machines which he used is copied to a large extent in the modern testing machines.

There have developed among people who deal with metals three more

or less distinct viewpoints, namely, that of the engineer who studies stresses, strains, and strengths; that of the metallographist who studies crystalline architecture; and that of the X-ray crystallographist who studies atomic structures.

We have long relied on the engineers' formulas—allowing a reasonable safety factor—in the design of our structural parts. Our veneration for mathematics has led us to overlook the fact that these formulas are based on assumptions and that the mathematics of Newton or Leibnitz cannot make correct an unjustifiable assumption. The assumptions used by the engineer are that (1) the material is uniform throughout and may be divided into very small identical parts; (2) the material is equally compressible in all directions, or is isotropic; and (3) stress is proportional to strain up to the elastic limit.

The first assumption of the engineer as to the uniformity of the material is immediately questioned by the metallographist when he looks at a microsection and sees a non-uniform arrangement of micro-constituents. To this the engineer answers that his formulas are "statistically true"; that although over a very small number of grains the stress may not be equal to P/a, if a large area is considered, the relationship is quite accurate. Under dead loads these formulas are satsifactory even though certain small parts of the structure are stressed greatly beyond the elastic limit. But where the stress is high, a crack may start which under repeated stress will spread and cause the part to fail.

The X-ray crystallographist thinks of the geometric arrangements of the atoms in metals; of interatomic bonds; of the distortion of the space lattice under stress. The distortion under stress may be elastic, but this is very doubtful. It is fairly certain that slip occurs with an interchange of atomic bonds which seems to improve the metal. In a crystal under repeated stress, slips may take place without distortion of the crystal, as may be illustrated by the bending back and forth of a pack of cards held in the hand. Continual slipping causes the formation of minute cracks. And so in the crystal, as with us mortals, a little slip is beneficial, but too much slip is ruinous. The boundary line between the stress which causes slips and cracks with slips predominating, and the stress which causes slips and cracks, with cracks predominating, is called the endurance limit.

A theory has been forwarded by Griffith, an Englishman, that all materials have within them submicroscopic cracks which are non-uniformly oriented; that when an external load is applied to the material there is an intensification of stress at these submicroscopic cracks which causes a spreading of the cracks. He argued that if he could orient all these submicroscopic cracks in the direction of the applied load, he would develop maximum strength. This he illustrated in an experiment with a very fine thread of glass which gave a tensile strength of 400,000 pounds per square inch, which value is very close to that calculated by the physicists to be the absolute coherence of this material.

In conclusion, it should be emphasized to the steel treater who has to account for the failure of hardened tools in service that stress is greatly

intensified at sharp angles, tool marks, drill holes, and sharp fillets; that minute cracks started by intensified stresses will grow under repeated stress and will ultimately cause failure by fatigue; that of four failures blamed on heat-treatment, three are due to improper design.

P. Peskowitz.

TRI-CITY CHAPTER

The February dinner meeting of the Tri-City Chapter of the American Society for Steel Treating was held on the evening of the 25th at the Davenport Chamber of Commerce. There were fifty members of the local chapter in attendance. Mr. Swan Hillman, master mechanic of the National Lock Company, Rockford, Ill., presented a paper on "The Art of Cold Heading."

A large number of products such as bolts, nuts and screws are manufactured from comparatively soft steels by the cold working process. Low carbon steels and low carbon alloy steels are used in the manufacture of these parts. The cold heading process is made up of a number of operations such as forgings, threading, knurling and cut-off operations. The roll threading of bolts and screws—a process developed many years ago—has reduced materially the cost of manufacture of these parts.

One of the most important parts of successful cold heading operations is that the materials be properly selected by a satisfactory inspectional method.

Mr. Hillman stressed the fact that in inspection the chemical composition, the soundness and micro-structure of the steel be such that it will respond most readily to cold heading processes. The question of dies are very important phases of the cold working of materials. Some of the parts manufactured are hardened and others are not, depending upon the work that the part is to perform.

Mr. Hillman pointed out that there are at the present time 55,000 types and sizes of bolts, nuts and screws in the specifications of the manufacturers of the country, and at the present time the Bureau of Standards in Washington in their program of reducing waste are standardizing specifications so that this large number of parts can probably be reduced to five or six thousand. This will represent a great saving not only to the manufacturer, but also to the buyer of these materials.

There are a number of plants in the Tri-Cities which are manufacturing bolts, nuts and screws, and many of the personnel of these plants were present at the meeting last evening, and it was the consensus of opinion that Mr. Hillman's paper was a very interesting and valuable one.

Mr. O. T. Muehlemeyer, consulting metallurgist, Rockford, Ill., led a round table discussion on the selection of tool steel. Mr. Muehlemeyer showed the necessity of the proper inspection and selection of tool steels and stressed the fact that the proper heat treatment was necessary in order to obtain the highest efficiency from the tools.

WORCESTER CHAPTER

The annual joint meeting of the American Institute of Electrical Engineers and the American Society for Steel Treating was held Thursday

evening, January 28, at the Hotel Warren. Sixty members were at the luncheon.

The speaker for the evening was Wirt Scott, representative for the Westinghouse Electric Company, whose subject was "Electric Heating for the Metal Industry." The lecture was illustrated with numerous stereopticon slides showing typical installations. Mr. Scott pointed out and discussed the six periods of development in commercial electric heating.

The first period was the introduction of glue pots and equipment of such nature where the convenience of the installation warranted its use.

The second field was the melting of steel and the advent of electric furnace steel. This field has since grown to include the manufacture of electric furnace cast iron for special high duty parts, for which ordinary cupola grey iron is not satisfactory.

The third application was the melting of brass and bronze for the making of castings.

Enamelling ovens was the fourth field to which electric heat extended.

Next commercial cooking was proven to be both economical and practical and many hotel and bakery installations have since been installed.

The sixth and last application has been to the heat treating field. Mr. Scott stated that in firms where the operating costs were best known, electric heating equipment was making the most rapid progress; three of the largest automobile manufacturers being practically 100 per cent electrified in their heat treating departments.

The speaker next discussed electric furnace design, its utility for the heat treaing process which it is to perform, its capacity, the distribution of heat and its temperature control. Regarding durability, the refractories if not run over 1600 degrees Fahrenheit will last indefinitely and there will be no warping of doors and frames. The heating units when correctly made and installed will give a minimum life of 15,000 hours. An alloy of 80 per cent nickel and 20 per cent chromium has been found the most satisfactory and any iron in the alloy will result in early failure.

The heating elements should be of ample size to insure a satisfactory life, should contain the least number of welds (every such point being the possible location for premature failure) and, the method of supporting the heating units so that the natural expansion and contraction may occur unhampered. With such precautionary measures taken by the builders the furnace will give a maximum of satisfactory service.

During the talk Mr. Scott answered many questions regarding the points brought out. *E. C. Clark.*

DILATOMETRIC METHOD OF HEAT TREATMENT

Discussion continued from page 419

traction is greater with the fiber than transversely to the fiber. I do not believe that the question of dimensional changes has a direct bearing on the papers this morning. I was prompted to give the above because the question of dimensional change was brought up by several of the speakers.

QUESTION: I would like to ask Professor Harder if he has had any experience in cut-away cross-sections. It seems that the talk has all been

on cross-sections that have been practically uniform. What I am alluding to is dies, for instance, sections that are not uniform in length, or are cut away, with holes in them. I should think there would be quite a difference there in the rate of expansion.

DR. O. E. HARDER: Mr. Chairman, we have not studied that particular thing. I can say that there are some other factors which have not been emphasized which must be considered with reference to dimensional changes. By that I refer to size of piece in different directions. If you take, for example, a cylinder, so that the length is considerably greater than the diameter, and heat that repeatedly, you get a badly distorted specimen. I think that in that case the specimen "necks down" in the middle and is drawn in at both ends. On the other hand, if you take a round so that the length is less than the diameter, you get another type of distortion. That depends upon the cooling at the edge, the amount of stress required to upset the piece in different directions, and those factors have to be considered, and by the time you get those in, you have enough complications that the study of dimensional changes in dies is almost impossible of complete analysis, it seems to me.

Items of Interest

THE International Nickel Company, 67 Wall Street, New York City, is publishing a series of twelve bulletins on nickel steel. The subject of Bulletin No. 1 is, "Society of Automotive Engineers Standard Specifications for Steels"; Bulletin No. 2 deals with "Physical and Mechanical Properties of Nickel Steels." Subsequent bulletins will be issued bimonthy. To facilitate filing, and to increase their reference value, loose-leaf binders 8⅝x11⅛ inches are furnished. These publications may be had upon request.

G. S. Rose formerly in metallurgical department of Alan Wood Iron & Steel Co., Narbeth, Pa., is now employed in the same capacity at the Park Works of the Crucible Steel Company of America.

Henry Disston & Sons, Inc., of Philadelphia, announce the appointment of Mr. E. A. C. Baum as assistant western representative for steel sales, with headquarters at the Disston Chicago branch, 111 North Jefferson Street.

Mr. Baum formerly was metallurgical engineer with the Illinois Tool Co., and comes into the sales field after many years of experience in the handling and use of tools and tool steels.

Mr. John K. Desmond, formerly with Philadelphia District Sales Office of the Crucible Steel Company of America, has been appointed Philadelphia District Manager of steel sales for Henry Disston & Sons, Inc.

H. C. Osman, sales manager of the Nugent Steel Castings Company, Chicago, has been elected secretary of the Company. He will continue to have charge of the sales for the company.

C. A. MacDonald, formerly secretary, has been elected treasurer.

A tool steel catalog has just been issued by Henry Disston & Sons, Inc., Philadelphia, descriptive of the various types of electric furnace tool and alloy steels which they manufacture. These include high speed, non-shrinking, fast finishing, hot and cold die, trimmer die, alloy chisel, and standard tool compositions. It is filled with valuable information on the uses, methods of heat treatment, and physical characteristics of these steels; and supplemented with useful tables of standard steel data, provides a convenient reference book wherever special steels are used. Copies of this new book may be had on application.

The Republic Flow Meters Company, 2240 Diversey Parkway, Chicago, is publishing a bulletin entitled "Measurement of Water," which is said to give much concrete information on the subject of metering water electrically. The bulletin consists of 16 pages and contains many illustrations.

It may be had by writing the Republic Flow Meters Company.

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EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

METALLURGIST AND CHEMIST desires change. Fourteen years' experience in automotive industry. Past experience includes charge of both physical and chemical laboratories, also heat treating departments. Location immaterial. Address 3-55.

METALLURGIST-CHEMIST, with 14 years' experience, embracing the nonferrous and ferrous industry, including the ferro alloys of tungsten, molybdenum and vanadium. Past work included physical testing, analysis, metallography, heat treating. Available on short notice. Address 2-20.

POSITIONS OPEN

WANTED: Alert, well-trained, energetic research worker, with good personality. Good general foundational training in metallography necessary, and several years' graduate, or equivalent work in an industrial laboratory, in nonferrous metallurgy, desirable. Salary commensurate with qualifications of applicant. Applicant please state qualifications fully and give references, age, nationality, religion, whether married or single, and salary desired. Address 1-20.

ENGINEER. Electrical or Mechanical. Recent graduate for sales engineering work in connection with electric furnaces and temperature control equipment. Answer in full, giving age, marital state, education, schools attended, experience, etc. State salary expected and enclose photograph. Address 3-5.

WANTED—Thoroughly experienced steel plant analyst; must be capable of handling all usual steel plant work. State age, experience and approximate salary expected. Near Pittsburgh. Address 2-5.

FOR SALE

FOR SALE: Leitz Micrometallograph (camera and complete microscope with optical equipment) in perfect condition. Address 2-15.

FOR SALE: Exceptional Leeds & Northrup Furnaces. Guaranteed Brand New. Will sell at very great sacrifice. L & N "Hump" Heat Treating Furnace—1 No. 8058 Furnace, inside dimensions, 8½ inches in diameter and 22 inches deep. One No. 8551—F—S Recorder. L & N Drawing Furnace—1 No. 9262—24 Furnace, inside dimensions, 12 inches in diameter and 24 inches deep. One No. 8970 Control Panel. One No. 8571—D—D—39 Controller. These furnaces were intended to through-harden automobile crankshafts made of ball-bearing steel which have been eliminated in the design and which has made the furnaces unnecessary. They were used only in a test, for a few hours. Address 3-40.

FOR SALE

BAUSCH AND LOMB microscope and accessories, also camera and stand for taking microscopic prints. Excellent condition and ideal for a student. Will sell at a sacrifice. Address 3-45.

1—Brinell Machine 12½" capacity for specimens. Price right. Address 3-10.

Leeds & Northrup Hump, furnaces with ammeters, controls and recording instruments equal to new; some never used. Price you must buy. Address 3-15.

1—Gleason gear hardening machine can be bought right. Address 3-20.

1—Eaton Electric furnace—8" x 18" x 36" temperature range 800 degrees Fahr., control, etc., included, will sell at a bargain. Address 3-25.

12—Leeds & Northrup Recording Instruments, single point in A-1 condition priced for quick sale. Address 3-30.

FOR SALE
1—Leeds & Northrup Potentiometer
1—Leeds & Northrup Optical Pyrometer
1—Scleroscope
1—Bausch & Lomb Photomicrographic Outfit
1—Bacteriological Microscope
Hess Steel Plant, Baltimore, Md.

FOR SALE—One-half interest in a well established commercial steel treating company. Long lease on building. Free of debt and making money. Full particulars on request. A snap for somebody. Ill health the cause for selling. Address all communications to Claude L. Acker, 655 Leib St., Detroit, Mich.

WANTED

WANTED—Metallographic Laboratory Equipment
Tensile Testing Machines
Hardness Testers
Microscopes
Photographic Apparatus
Small Annealing Furnaces } Gas / Electric
Small Crucible Furnaces } Oil
Pyrometers
Send descriptive literature and prices. Address 2-10.

1—Fifty to One Hundred Thousand, Reahle or Olson Tensile Testing machine which must be in first class condition and the price right. Address 3-35.

SCLEROSCOPE WANTED, dial type. State price and length of time in use. Address 3-50.

Thousands of dollars that might otherwise be spent for expensively equipped laboratories are being saved for at least four industrial firms in the Pittsburgh District this year under a plan whereby employes of these companies, it is reported, are conducting research work in metallography in the Bureau of Metallurgical Research of the Carnegie Institute of Technology.

Listed as night students and scheduled to attend an advanced class in metallography once a week during the night college year, ten men are at work in the Bureau this year conducting a unique experiment in co-operative research that may eventually result in the saving of incalculable funds to the metallurgical industries of the Pittsburgh District.

According to a report of the plan, the class of ten men, which includes the manager of one of the steel companies, took a night course last year in elementary metallography, under Dr. V. N. Krivobok, research associate, of the Bureau of Metallurgical Research. After completing the elementary work, the students were offered the opportunity to continue their studies for the current year with the privilige of selecting their own or their company's problems in metallurgical research for intensive study. The result has been that five different problems in metallurgy are now being studied by the ten men, three of the studies being made in behalf of their employers, and two being investigated at the suggestion of Dr. Krivobok.

The significance of this plan, the report points out, is that both the industry as a whole and the individual companies interested in the research problems, will be mutually benefited and at the saving of funds that might be expended privately to attain the same results.

Under the direction of Dr. Krivobok, the entire facilities of the Bureau, which has been established two years, are available to the students. Among the problems under investigation are (1) heat treatment for the production of highest possible physical properties in steel castings of varied carbon content; (2) heat treatment of steels of exceptionally high carbon content; (3) investigation of low carbon high manganese steels; (4) investigation on aluminum steels; and (5) investigation on dendritic segregation in chromium steels. The first three problems are being studied, according to the report, in the interests of employers of the students.

Another class of 30 night students is also engaged this year in a study of elementary metallography, and under Dr. Krivobok's plan, an advanced class in metallographic research will be organized for this group next year. Members of the advanced class already at work on research will also be given the privilege of continuing their studies during the following year, it is announced, thus making it possible to centralize in the Carnegie Institute of Technology an extensive amount of important research work.

The United States Civil Service Commission announces the following open competitive examination for the positions of Associate Engineer, $3,000, and Assistant Engineer, $2,400.

Receipt of applications for these positions will close April 30. The first rating of papers will begin March 15, 1926; thereafter papers will be rated as received until the close of receipt of applications.

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To Polish Metallographic Specimens

—so that scratches do not re-appear upon etching

FISHER LEVIGATED ALUMINA

For Metallographic Polishing

This alumina is carefully levigated. The levigated product is again graded into Grades No. 1, No. 2, and No. 3, and then chemically treated and prepared to make a product which has the proper degree of suspension, adhesion, and hardness. The polishing solutions made from the following grades of alumina are readily applied to the felt by means of a laboratory wash bottle, or a bottle with one-hole stopper and a glass tip.

This alumina is now recognized by the leading metallographists as the most satisfactory material for polishing metal surfaces for microscopical examination and photography, and is recommended in the newer text books on this subject. It produces a highly polished surface free from scratches, and does so without encasing the scratches. Polished surfaces, produced by materials which encase scratches, show such scratches after being etched.

Grade No. 1—for Hard Metals - - - - $1.00 per oz. (makes 50 ozs. solution)
Grade No. 2—for Medium Hard Metals - - 1.40 per oz. (makes 100 ozs. solution)
Grade No. 3—for Soft Metals - - - - 1.80 per oz. (makes 150 ozs. solution)

Fisher Polishing Alumina is only one of the many items in our new catalogue which facilitates the work in Metallurgical Laboratories. This catalogue will be sent without charge to Metallurgical Laboratories

FISHER SCIENTIFIC COMPANY

LABORATORY SUPPLIES

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Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the postoffice or customhouse, any city.

The American Engineering Standards Committee and the National Screw Thread Commission have invited the British Engineering Standards Association to a conference to consider the possibility of unifying the American and British screw thread systems.

Both the American and the British system of screw threads have been the result of a long national development, the basis for the American system having been laid by William Sellers in 1864, and that for the British system by Joseph Whitworth in 1841. The standard threads are called "American (national) standard thread" in this country, and "British Standard Whitworth (BSW) thread" in Great Britain. In so far as the number of threads per inch for the various diameters are concerned, the two national systems correspond to a large extent. As a matter of fact, considering the American series of standard coarse threads, there are only two cases in which the British have a number of threads different from that adopted by the Americans for the same diameter. These cases are the ½" bolt for which the Americans have adopted 13 threads per inch against the British 12, and the 3-inch bolt for which these figures are 4 and 3½ threads per inch, respectively.

A fundamental difference between the two national systems exists, however, with regard to the angle of thread. This angle is 60 degrees for the American, and 55 degrees for the British thread. Another difference, of less importance, consists in the American thread having flattened crests and roots, whereas those of the British Whitworth thread are rounded.

The importance of a possible unification between the two screw thread systems will be obvious if one realizes the innumerable applications of threaded parts in modern manufacture. One large manufacturer uses 20,000,000 bolts of the half-inch size alone in its annual production of machinery and equipment. The use of smaller bolts is on a still greater scale. By unification, an enormous number of threaded parts of the same kind, such as bolts, nuts, screws, etc., would then become perfectly interchangeable on an international scale.

Invitations to the conference between the British and the Americans have also been issued to the Canadian and the Australian national standardizing bodies.

The invitations have been issued with the understanding that no final decision in the matter will be taken until after the problem has been considered in a general international conference to which all of the twenty existing national standardizing bodies will be invited. Whitworth thread, though originating in England, is used to a great extent in other countries, and has even been adopted in several of these countries, which are therefore much interested in the outcome of the discussions of this subject between the British and the Americans and its ultimate effect upon their own corresponding standards.

The American Engineering Standards Committee has been requested by the Society of Automotive Engineers to take up the unification of wire and sheet

(Continued on Page 38 Adv. Sec.)

Permanent Magnet Steel

Composition is but one factor in the making of Permanent Magnet Steels. Thermal treatments before the steel goes to the customer are governing factors in obtaining proper values in finished magnets.

Simonds magnet steels are furnished in both Tungsten and Chromium grades in sheets, strips or bars. When required in the annealed condition, a special anneal is given, depending on the method of magnet manufacture. This anneal, while softening sufficiently to allow of cold working or blanking, is so-regulated as to prevent loss of magnetic properties. Ordinary annealing will lower perceptibly these important values.

We maintain a magnetic testing laboratory for our own development work and to co-operate with our customers in helping them to produce a product of the highest quality. This service and our experience are available to those interested in producing high grade permanent magnets for meters, magnetos, radio work and the like.

We welcome the opportunity to improve your product, and to solve any of your present problems.

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metal gage systems in order to arrive at a national standard system of designating the diameters of metal wires and the thicknesses of metal sheets. The systems of gage numbers by which these products are generally designated at present have been developed and adopted in the course of time in different trades and for different products, as steel and copper wire, aluminum, brass and zinc sheets, etc. In the request submitted by the Society of Automotive Engineers there are listed 13 gage systems now in use in this country. For example, the "American wire gage" or "Brown and Sharpe gage," which is widely used for non-ferrous wires (copper, brass, aluminum) was devised in 1856 by the founders of the Brown and Sharpe Manufacturing Company and adopted by the Association of Brass Manufacturers in 1857. The name "American wire gage" is of a later date. Steel wire, however, is indicated by various systems of gage numbers which not only differ from the "American wire gage" system for the copper wire, etc., but also differ from each other. Thus, according to present practice in this country, a copper wire number 6, "American gage," has a diameter of 0.162″; a steel wire number 6, "United States steel wire gage," has a diameter of 0.192; while "Stubbs steel wire," number 6, has a diameter of 0.201″; and sheet steel according to the "United States standard gage," number 6, has a thickness of 0.1992. This wide diversity necessarily leads to confusion. Errors frequently occur in the filling of orders and in industrial work in general. Some organizations, in order to avoid confusion, have entirely done away with gage numbers and designate wire and sheet metal sizes exclusively in decimal fractions of an inch.

A conference of all industrial groups interested in this problem will be called in the near future, to discuss the desirability and possibility of unifying the various existing gage systems into a consistent national system, or systems.

A question which is closely connected with that of the designation of wires and metal sheets is whether or not it is feasible to thin out the series of diameters or thicknesses actually listed in the catalogues of the different trades. Inasmuch as a procedure of this nature involves the element of "simplification," the American Engineering Standards Committee and the Division of Simplified Practice of the Department of Commerce have made arrangements to cooperate actively in this matter. The latter body will undertake to bring about production surveys in the trades concerned, in order to find out the relative importance of wires and sheets made to the several gage numbers.

In the meantime, any suggestions with regard to the general technical problem, or any of its phases, will be welcomed by the American Engineering Standards Committee, whose address is 29 West 39th Street, New York City.

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